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OF THE
GEOLOGICAL SURVEY OF INDIA.

VOLUME XXX.

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RECORDS

THE GEOLOGICAL SURVEY OF INDIA.

Part I.] **1897.** **February.**

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1896.

1. At the commencement of the year the disposition of the officers of the Survey was that stated in the last annual report. During the year Dr. Warth and Mr. Anderson resigned their appointments, the first on the 15th March, the second on 1st September 1896.

Two officers have been granted furlough. Mr. Griesbach on 16th May, Mr. Datta on 17th September 1896.

Both sub-assistants are absent on leave, Lala Kishen Singh on medical certificate from 1st October 1896, and Lala Hira Lal on privilege leave.

Dr. Noetling and Mr. Bose have been absent on furlough throughout the year.

Mr. LaTouche returned from furlough on 13th October 1896.

2. Owing to retirements and departure of officers on furlough, the Survey is working very short-handed during the present year; the disposition is as follows:

MR. MIDDLEMISS	.	.	.	.	} Madras.
HOLLAND	.	.	.	.	
LA TOUCHE	.	.	.	.	Western Rajputana.
SMITH	.	.	.	.	Assam.
VREDENBURG	.	.	.	.	South Rewah.
GRIMES	.	.	.	.	Burma.

Sub-Assistant Hira Lal will be posted to Madras on return from privilege leave, if his services are required by Mr. Middlemiss; if not required, he will be kept at head-quarters to assist in the transfer of the office of the Survey into the new building.

3. *Madras.*—The survey of the Salem and Coimbatore Districts has been energetically pushed forward, and it is expected that it will be completed in 1897, when a full report of the results will be submitted. The most important of these at present is the conclusion Mr. Middlemiss has come to, that the massive granitoid gneiss of Hosur, which had been regarded as probably older than the other types (*Manual*, 2nd edition, p. 35), cannot be said to be older or younger than the charnockite gneiss, or to underlie or overlie it. At the limits of the two types of gneiss, they

Mr. C. S. Middlemiss.
" F. H. Smith.

are seen to end in long tongues which interlock with each other, while a perfect mineralogical passage from one type to the other has been observed.

4. In the neighbourhood of Satyamangalam, some patches of quartz schist, containing numerous crystals of kyanite—which was at one place reported as corundum—are regarded by Mr. Middlemiss as probably highly metamorphosed Dharwars. The southern extensions of the main outcrops of this series, in its typical form, have been mapped. In many cases, the nature of the boundary suggests that the gneiss is in reality an intrusive granite, as there is a band of it crowded with fragments of Dharwar rock, resembling inclusions. This is not the true explanation according to Mr. Middlemiss, however, as there are many sections where the Dharwars are clearly unconformable on the gneiss; and he considers that the apparent inclusions have been produced by a post-Dharwar softening of the gneiss and movements of the rock while in this condition.

5. An interesting fact in connection with the Dharwars, which may be noticed here though we owe it to Dr. J. W. Evans, Senior Geologist to the Mysore State, is the discovery that the so-called reefs of the Kolar goldfield are not reefs in the ordinary sense of the word, but true interbedded quartzites of the same character as the famous gold-bearing deposits of the Transvaal.

In the neighbourhood of Kollegal, some gold-bearing reefs were examined by Mr. Middlemiss. One of these near Kavudahalli (Cowdalli) Gold. is now being exploited by a mining company and good lodes carrying 1 to 2½ ounces of gold to the ton are said to have been found. It is noteworthy that Mr. Middlemiss considers that the rocks of the Kavudahalli field do not belong to the Dharwar series, as was suggested by Mr. Foote (*Records* XXI, p. 55). Mr. Foote, it must be remembered, had not visited this locality, and his suggestion that the Dharwar series might be represented there was purely an inference from the known existence of old workings, and the fact that in the country he had surveyed all the gold-bearing rocks were confined to the Dharwar series. It was known that the gold of the Wynaad occurred in rocks very different to those of the Dharwar series in its typical exposures, but in the absence of a special examination, the possibility remained that the difference might only be due to a greater degree of metamorphism. Mr. Middlemiss' work makes it more probable that the difference is a real one, and that the gold of Southern India is bound in two different rock systems and is not confined to one. The discovery, noticed above, that the gold-bearing rock of the Kolar goldfield is a true metamorphic quartzite, suggests that the gold is of derivative origin, and is consequently an independent indication of an older series of gold-bearing rocks, from which the gold was derived.

6. Concurrent with the purely geological survey, the special investigation of the corundum-bearing rocks has been actively carried on, and Corundum. has resulted not only in the discovery of many new localities, but, what is more important, of the fact that the corundum occurs in definite bands of rock which can be followed with almost the same certainty as a seam of coal. One such band—known as the Paparapatti band—has actually been traced continuously for a distance of 36 miles.

7. The preliminary survey being sufficiently advanced to render the commencement of exploratory workings desirable, with a view to testing the extent and richness of the corundum-bearing rock, arrangements were made with the Govern-

ment of Madras for the carrying out of this work. Owing to the resignation of Mr. Anderson—who had been intended to take charge of this work—a modification of the original plans had to be made, and it was arranged that a series of excavations should be made by the Public Works Department, at places to be pointed out by Mr. Middlemiss. These excavations or quarries as they will be, are intended to show the thickness of the corundum-bearing bands, and whether they are continuous or occur as lenticular patches. A fair average sample of the rock extracted, of sufficient size to give a trustworthy estimate of the richness of the rock, is to be carefully cleaned by hand and the proportion of corundum to matrix determined by weighing. Samples of the cleaned corundum and of the rock will then be sent to the Secretary of State for submission to experts with reference to (1) the value of the cleaned product and (2) the best means and probable cost of separation. Owing to the fact that each crystal of corundum is surrounded by a shell of felspar, from which it separates as readily as the kernel of a nut from its shell, there will be no difficulty about the mechanical separation of the corundum from its matrix, and the whole question of the possibility of working these deposits on an industrial basis will resolve itself into the three questions, of quantity of ore, value of the finished product, and cost of production. The first of these will be determined by the operations carried out locally; for the latter two, the reports of the experts will give the answers. In this manner, a result will be attained both more satisfactory in itself and more economically than by the employment, on purely exact executive work of a nature that does not require any very high standard of attainments, of a highly paid specialist, who would not have been able to answer the questions which must be submitted to European or American experts.

Operations are now in active progress, and the results of the first weighings give 150lbs. of clean corundum from 1 ton of rock.

8. Several new discoveries of iron ores have been made during the progress of the survey and previously known sites re-visited. An application has also been made by the Government of Madras for the examination of the iron ores of Kurnool, but in view of the report of Mr. Jeremiah Head, addressed to Her Majesty's Secretary of State for India, dated 2nd May 1896, which shows that there is no possibility of locally manufactured charcoal iron competing with the imported product, all special investigations of iron ores in Madras would appear to be a waste of time. In the case of the iron ores of Kanjamalai, near Salem, it has been decided to send 100 tons home for an exhaustive trial on a large scale, and until the results of this are known, any special examination of iron ores, apart from what can be done in the course of regular survey, is to be deprecated.

9. In February an application was made by Messrs. Sugg and Company for a consignment of 20 tons of steatite from the Kurnool District and this department instructed to inspect the consignment before despatch. The necessary instructions were accordingly issued to Mr. Middlemiss, who reports that of the 28 tons, which were extracted by the District authorities, a large part was in too small fragments to be of any use, and only a very small proportion reached the dimensions which appear to be required. He has condemned 13 of the 28 tons and recommended that the other 15 be forwarded to Messrs. Sugg and Company for trial.

10. *Bengal*.—At the commencement of the year, the party was still engaged on exploration, but in February a site was selected by Mr.

Chota Nagpur.

Mr. W. Anderson.

Dr. H. Warth.

Lala Hira Lal.

Anderson where mining operations were commenced and stamps set up, but there was great delay in starting them, a delay ostensibly due to the non-supply of certain requisite stores, the exact description of which I had great difficulty

in obtaining from Mr. Anderson. The final results of the crushings were disappointing and inconclusive beyond showing that the quartz at Dhobni near Borobhum, worked by Mr. Anderson, contained practically no gold.

11. *Central India*.—During the working season of 1895-96 the survey of Rewah

Rewah.

Mr. R. D. Oldham.

„ P. N. Datta.

„ E. Vredenburg.

„ G. E. Grimes.

had been practically completed and would doubtless have been finished, but for the phenomenal unhealthiness of the season, Messrs. Datta and Grimes were both completely prostrated before the end of the season, while among the establishment and servants fever was rampant.

12. The work in the rocks which have been grouped for convenience as transition has resulted in the establishment of at least one well-marked unconformity. The existence of this had been suspected from the previous season's work, but, though now well established, it will not be possible at present to devote the time necessary for detailed mapping to the determination of the exact distribution of the two series. It is also extremely doubtful if this could be done without a more perfect topographical map, on a larger scale than is at present available.

13. In the Vindhyan system, Mr. Datta's survey seems to show that there is a complete conformity between the lower and upper Vindhyan along the boundary at the foot of the Kaimur scarp. Certainly if there is any unconformity it is of the slightest, extremely difficult of detection, and in most striking contrast to the well-marked unconformity observable a few miles to the southwards, as described in *Records XXVIII*, p. 139. This contrast in the relations of the series at places, so close together, is a strong support of the suggestion regarding the nature and mode of origin of the Vindhyan sandstones, first propounded in the *Manual of the Geology of India*, 2nd edition, p. 104.

14. In the Gondwana area, the survey of the western extension of the Singrauli coalfield was carried out and some discoveries of interest made in the course of it. In the Talchirs of Singrauli, a large number of the included boulders were found to show striation and polishing, resembling that to be seen on the boulders in glacier moraines, and more especially in what is known in Switzerland as "Grund Morän." This is not only a new locality for these scratched boulders, but one in which they are more abundant and perfect than has yet been recorded from the Talchir boulder bed of the Peninsula.

15. In the area occupied by the Damuda rocks, a number of coal seams were observed; the assays of the specimens brought to Calcutta

Coal.

have given poor results; but it must be remembered that they were only weathered specimens from the outcrop. There is here a large coalfield with an abundant supply of coal, but too remote from the existing lines of communication to hold out any prospect of successful working in the immediate future.

16. An interesting collection of fossils was made; amongst them, a cluster of

fronds of *Glossopteris* attached to their rootstock, which shows the characters of *Vertebraria*. A somewhat similar discovery of *Glossopteris* fronds attached to *Vertebraria* has been recorded from South Africa,* and the true nature of that mysterious fossil known as *Vertebraria* may now be taken as settled.

17. It is noteworthy that the numerous intrusions mapped are all basaltic and that none of the peridotites which have been described by Mr. Holland from the eastern coalfields of Bengal were observed.

18. *Baluchistan*.—During the working season of 1895-96, Sub-Assistant Kishen Singh was engaged on the survey of the Chehiltan range and part of the Khwāja Amrán, and in the collection of fossils from the hills near Khelat. According to his report, the Khojak shales underly the 'massive limestone' (jurassic) with a marked unconformity. This observation, if confirmed, is inconsistent with the eocene age ascribed to the former rocks by Mr. Griesbach in his original report (*Memoirs*, XVIII), and subsequently confirmed by the discovery of nummulites, as announced in the Annual Report for 1894; on the other hand, it is in accordance with the conclusion, adopted in the second edition of the *Manual*, that these shales are older than tertiary, and not impossibly triassic in age. The grounds for this correlation are, as was stated, very inadequate; no fossils had then been found in any part of them, and it was only the exigencies of classification that led to any definite age being ascribed, even conjecturally. The most probable explanation is that the Khojak shales belong to more than one stratigraphical series, and that the apparent discrepancy will vanish when this region is fully surveyed.

19. The collection of fossils from the neighbourhood of Khelat has not yet been examined, but Dr. Carter's discovery of *Orthoceras* has not been repeated.

20. *Rajputana*.—The survey of Rajputana has been resumed during the present working season, and Mr. LaTouche is engaged in Southern Marwar. The commencement of field work was delayed by causes beyond control and no results of importance can yet be reported.

21. *Punjab*.—During part of the recess season, Mr. Hayden was deputed to complete the geological survey of Simla and Mahásu, of which a preliminary account was published in *Records*, Vol. XX, p. 143. Besides some minor modifications in detail of the mapping of Simla proper and the extension of the survey over the Mahásu ridge, Mr. Hayden was able to complete the examination of Jutogh, to which I was unable to devote more than a slight attention in 1887, and to determine in detail the sequence of the rocks grouped as the upper or Jutogh carbonaceous slates and limestones.

22. In the course of this survey, some light has been thrown on a vexed question in the geology of Simla and Jutogh. It has long been known (see H. B. Medlicott, *Memoirs* III, pt. 2, p. 34) that the rocks at the summit of Jako show a much higher degree of metamorphism than in the bottoms of the surrounding valleys; where we find slates and phyllites, from which there is a passage, as the hills are ascended, though more and more schistose rocks, to a highly crystalline garnetiferous mica schist. In 1887, I discussed the three alternative explanations which were possible, but the facts then collected were insufficient to decide between them. Mr. Hayden's observations indicate the probability that, in the case of

* R. Zeiller. *Comptes Rendus*, CXXII, p. 744, and *Bull. Soc. Geol., France*, 3rd Ser., XXIV, p. 349.

Jutogh at least, there is a central core of igneous rock to whose intrusion the metamorphism of the beds is due. He finds that the whole series of beds on the Jutogh hill show unmistakeable signs of contact metamorphism and in two places intrusive diorite was found in the form of numerous dykes and veins cutting the sedimentary rocks, which had been altered almost beyond recognition.

23. *North-Western Provinces.*—The investigation of the stability of the hill sides in Naini Tal has been completed and a full report published. As originally proposed, this investigation was to have been carried out by an officer of the Geological

Naini Tal.

Mr. T. H. Holland,

Survey in conjunction with an Engineer and was to have included specific recommendations as to protective measures to be undertaken. Owing to various causes this programme was not carried out, and the investigation and report were made by Mr. Holland alone. It is a very complete and, it is anticipated, final statement of the conditions of the problem, the nature of the dangers to be apprehended, and the character of the remedied measures required. The execution of these, when decided on, must be left to the Public Works Department, which will find in Mr. Holland's report the fullest information regarding those aspects of the problem which would not come within the cognizance of its officers, but which must be attended to if more harm than good is not to result from its operations.

24. *Assam.*—The survey of Assam has been resumed during the present working season, and Mr. Smith is at present engaged on the survey of the eastern part of the Mikir hills. It is hoped

Mr. F. H. Smith.

that some light may be thrown on the manner in which the cretaceous and nummulitic rocks pass north-eastwards, and on the manner of their final disappearance. It is probable too that coalfields of value to the Assam-Bengal Railway may be met with in the course of the survey.

25. During the field season of 1895-96, Mr. Hayden was employed in Burma,

Burma.

Mr. H. H. Hayden.

„ G. E. Grimes.

following the precedent of former years, under the direct orders of the Local Government. After the completion of the examination of the Sagyin ruby tract, which was referred to in last year's report, he was instructed to examine the Mithwe coalfield, a yellow ochre deposit near Panpé, and the steatite mines which were reported to be situated in the Minbu District, but which were found to be in the Kyaukpyu District of Arakan.

26. The Mithwe coalfield is situated about 5 miles south-east of Lagat and consists of tertiary clays, sandstones and conglomerates.

Coal.

The coal occurs in thin seams, the best of which is 2' 8" thick, but only extends for 112 feet along the outcrop; it is shaly and poor, and the beds are highly disturbed, faulted, crushed and penetrated by intrusions of gabbro, diallage rock and serpentine.

27. Of the yellow ochre deposit little more need be said than that it exists, with a varying thickness, whose maximum is 30 feet.

Ochre.

28. The steatite of the Kyaukpyu District is found in considerable quantity and has hitherto been mined at two localities, about 30 miles

Steatite.

west of the village of Hpa-aing and near Senlan village in Ngape township. Both these villages are in the Minbu District, but the first named mines are on the west on the watershed, and consequently in the Kyaukpyu District. The mines descend as much as 200 feet by narrow tortuous shafts,

and are abandoned in the rains owing to the influx of water, and the risk the miners run of finding themselves shut in by falls of rock in the untimbered shafts and galleries.

29. These results cannot be regarded as satisfactory either from a scientific or economic point of view. For this, Mr. Hayden can in no way be held responsible; on the other hand, his work, carried on under circumstances of exceptional difficulty, attended by no small hardship, and in spite of his being hampered by the want of proper maps for the execution of a geological survey, the scattered distribution of the localities visited, and by the imperfect, where not misleading, information supplied to him, is deserving of the highest praise. The failure can only be ascribed to the conditions under which he worked, conditions which were necessary and advisable in the early days when the province first came under British rule, but which had unfortunately been allowed to survive their utility. All the principal known mineral tracts of Upper Burma have now been visited and examined as far as can be done in the absence of accurate topographical maps, and it is not to be expected that the Local Government, having no responsible adviser, should be able to profitably direct work of so technical a nature as the geological survey. The system has now been ended, and the geological survey in Burma been put on the same footing as in other parts of the Empire.

30. The report on the Yenangyoung oilfield, referred to in the last annual report, is now in a very forward state, and will be published shortly.

Petroleum.

In it, Dr. Noetling shows that the Yenangyoung field is already showing signs of exhaustion, and in view of this, and his belief that the field has only a few more years of life, it was determined to take up the survey of the country between the Yenangyoung and Yenangyat oilfields, with a view to determining whether there was any reasonable prospect of a fresh oilfield being found in that tract. Mr. Grimes was deputed for the work and started for Burma at the end of October; good progress has been made with the survey and already indications have been met with of the existence of a fresh oilfield, but no more definite statement can at present be made.

31. On his way to the ground, Mr. Grimes visited the Yenangyoung oilfield in order to make himself acquainted with the rocks he would meet with during his survey, and in the course of this visit observed an interesting improvement which had been adopted by the well-diggers. Formerly, the stay which a digger could make at the bottom of a deep well was to be timed by seconds, while a long period of rest at the surface was required to enable him to recover from the effects of the noxious vapours he had inhaled. Mr. Grimes noticed that they had now adopted the use of a diving dress, without the heavy weights required for work under water; the use of this apparatus has been introduced during the last five months, and there are already six machines at work. One result is the cheapening of the excavation, for instead of remaining down only a fraction of a minute at a time, the workman can now stay down for hours; another is that the depth to which a well can be dug is increased, instead of being limited to about 300 feet on account of the great difficulties encountered under the old system; and a third—the consequence of the last—is an increase of the life of that part of the field which is worked by the native method.

32. Museum and Laboratory.—Mr. Holland has continued his petrological

Mr. T. H. Holland.
Mr. T. R. Blyth.

studies of Indian rocks, the principal of which, during the past year, has been a study of the basic intrusive rocks of ancient date. A series of these, penetrating the crystalline

rocks of Southern India, had been regarded as the underground equivalents of the lava flows of the Cuddapah series; the petrological examination has confirmed this supposition and has besides shown them to be of unusual interest in themselves.

33. The rocks are divided into three groups, which, though separated for convenience of description, pass into one another by imperceptible gradations. They are (1) olivine norite group, (2) augite norite group, and (3) augite diorite group. The order of succession of the minerals is constant throughout, the late development of the felspar in the basic types giving rise to a remarkable micropegmatitic structure.

34. The olivines in the more basic members show remarkably well-developed "reaction-borders," where they come in contact with the plagioclase crystals, and Mr. Holland has discussed the bearing of the evidence they offer on previously recorded conclusions concerning similar phenomena.

35. The most interesting feature, however, is the constant presence of micropegmatite in the augite diorite group, playing the part of groundmass to the previously crystallized felspar and pyroxene. Mr. Holland regards these patches of micropegmatite as the result of a distinctly late phase in the consolidation of the rock, and discusses the interesting bearing of these facts on the association of these basic rocks with granophyres and on the almost constant miarolitic structure of the latter rocks.

36. An important study of the corundum-bearing rocks of India has also been completed, in connection with the preparation of a memoir on the subject, now ready for the Press; this has resulted in the discovery of some interesting facts in connection with the paragenesis of this important mineral, and especially with regard to its relations with the pyroxene granulite series, so largely developed in Madras. At Singanamaranhalli, in the Hunsur taluk of Mysore, the corundum beds were found by Mr. Holland to be associated with an intrusion of olivine-bearing rocks, similar to those of the well-known Chalk Hills near Salem, and large masses of a rock composed of a highly ferriferous enstatite with magnetite and the iron-alumina spinel, hercynite. The association here is very strikingly like that of the rocks in which the corundum (emery) occurs in the Cortland series of New York State, where there is a development of pyroxenic granulites and ultrabasic rocks, presenting characters precisely similar to those of the charnockite and norite series in South India. A similar association of corundum with hercynite, magnetite, and rhombic pyroxenes has been described on the eastern edge of the Bohemian Forest, the original home of the mineral hercynite. Specimens obtained from the Hindupur taluk of Bellary district show an immediate contact of corundum with hercynite and magnetite, whilst in Chennimalai, Erode taluk, Coimbatore district, corundum crystals are found surrounded with hercynite.

37. These occurrences of corundum stand in apparent contrast to those which have been described by Mr. Middlemiss in the Salem and Coimbatore districts, where, instead of being associated with ultrabasic rocks, the corundum appears as a member of the ordinary gneisses and is never far from intrusions of graphic granite. Such also seem to be the relations of the blue corundum discovered by Dr. Warth

in Manbhum district of Bengal. In describing the latter specimens, Mr. Holland has compared them with a similar occurrence of blue corundum with kyanite, andalusite, and damourite in Virginia, United States of America, in which Dr. Genth considers the last-named three minerals as derived from the corundum; but the Manbhum specimens offer no support to such a conclusion. The corundum crystals are well formed, with lustrous faces, and are small compared with the beautiful great crystals of kyanite, in which they lie without apparent regularity of crystallographic disposition. If the latter mineral and the mica were formed by change of the former, there would surely be the usual signs of etching and irregularity of contour due to decomposition. The case seems a very simple one of separation, under conditions of free molecular movement, of the excess of the simple base, alumina, followed by a crystallization of its silicate as kyanite, the mica being secondary and derived by irregular change of the latter mineral. Such a conclusion is in agreement with the facts and is in accordance with the commonly-observed order of events in most crystalline rocks.

38. *Personnel*.—With the end of 1896, Mr. Holland's charge of the Museum and Laboratory has terminated, as the decision has been arrived at that it is necessary, in the interests of the public service, that he should acquire a practical experience of the ordinary field work of the Survey. During the six years he has been in charge of the Museum, the record has been one of continuous progress. In addition to the numerous petrological researches and economic enquiries to which previous annual reports and the publications of the Survey bear witness, the whole of the mineral and rock collections have been rearranged, the rocks, numbering over 17,500 specimens, have been re-registered and put into such order that any required specimen can be promptly referred to, and the specimens exhibited to the public completely rearranged; the mineral and economic collections amounting to over 18,000 specimens were left in perfect order by Mr. Mallet, but the growth of the collections since his retirement has necessitated much work in rearranging the specimens to make room for the additions, and the collection has been revised and re-labelled. A guide to the mineral collection has been published, while guides to the collections of rocks and of economic geology are being prepared and will appear in due course.

39. It is not, however, too much to say that this record of work done would have been impossible, but for the zealous and efficient assistance of Mr. Blyth, whose services have been recognized by the Government of India, and rewarded by a permanent increase of salary.

40. Little work has been done in the collection of fossils, which have unfortunately fallen into a state approaching disorder. This is to be attributed in part to the lengthened absences of the Palæontologist from Calcutta, but mainly to the absence of any competent assistant to take charge of the collections and see to the necessary routine of posting the registers, storing the specimens, and attending to the periodical cleaning of the cases and renewal of labels. Mr. Blyth's time is already fully occupied, and the appointment of another assistant has become imperative if the large and valuable collection of fossils is not to lapse into a state of chaos.

41. During the year the Survey has lost the services of Dr. Warth, who retired on pension on 15th March 1896, and Mr. W. Anderson, who resigned his appointment on 1st September. Neither of these vacancies has been filled up, and as regards

the last mentioned, it is doubtful whether any advantage is to be derived from attempting to fill it up. Experience has shown that it is practically impossible to obtain men of the stamp desired when Mr. Anderson was appointed, and the reason is not far to seek. Men with technical knowledge of exploitation of minerals naturally prefer to take service with mining companies, from whom they not only expect higher salary than they are likely to get in the service of the Government, but from whom they may expect as the reward of zeal and competence, a permanent employment on an increasing income, as the venture they conduct advances in prosperity. It is also very doubtful whether the services of such men are either necessary or desirable for the work which alone can be reasonably expected of the Government. I am strongly of opinion that it will be in every way more satisfactory that all economic investigations should be carried out under the scientific supervision of the permanent officers of the Geological Survey, and that the only special assistance required is for the sinking of quarries, shafts, or bore holes, as the case may be. This is the procedure which has been adopted for the investigation of the corundum deposits of Madras (para. 7), and I would urge that the experiment be given a fair trial before a highly paid so-called specialist is again appointed to carry out work, which is well within the competence of the permanent staff of the Survey.

42. Messrs. Vredenburg and Grimes were employed in Rewah during their first season. Mr. Vredenburg has shown great thoroughness and care in the work entrusted to him and gives promise of becoming a thoroughly efficient member of the Survey. Mr. Grimes was much hampered by ill-health as already noticed; when sent into a country, the rocks of which were unknown to him, except from printed descriptions, he showed considerable power of adapting himself to the changed circumstances and has done creditable work. I have considered that he, as well as Mr. Vredenburg, may be trusted with independent charge, and they have been employed in Burma and South Rewah respectively, as has been mentioned above. Reports received from both during the past three months have shown satisfactory progress in spite of considerable difficulties encountered.

43. *Publications.*—The long-delayed Memoirs on the Bellary district, by Mr. R. B. Foote, F.G.S. (Vol. XXV), and on the Hazara district, by Mr. C. S. Middlemiss (Vol. XXVI) have been published. The contents of both have been noticed in previous annual reports. Of the *Palæontologia Indica*, part 1, Vol. I, Series XVI, The Fauna of the Kellaways Mazar Drik, by Dr. Noetling, has been published. Parts 2 and 3 of the same volume and Dr. Diener's description of the lower trias fossils of the Himalayan collection are well advanced towards publication, as well as Dr. Noetling's Memoir on petroleum in Burma. In addition, the report on the geological structure and stability of the hill slopes around Naini Tal has been published, to which reference has already been made.

44. During the year two important papers have been published bearing on Indian geology. The first of these is the description by M. Zeiller of a collection of fossils from the coalmeasures of the Transvaal, to which reference has been made in para. 16. The second is the long-expected description by Professor Judd* of the collection made by Mr. Barrington Brown from the ruby mines of Upper Burma.

The crystalline limestones in which the rubies occur are associated with pyrox-

*Phil. Trans. CLXXXVII, p. 151.

enic and scapolite-bearing rocks, resembling the pyroxenic (hypersihene-bearing) rocks of Madras. These limestones are regarded as an extreme form of alteration of lime-bearing pyroxene gneisses, the formation of scapolite being described as a step in the formation of calcite from plagioclase felspar. The source of the alumina and magnesia in the rubies and spinels, and of the calcite in which these minerals are imbedded, is taken to be the basic lime felspar (anorthite) and associated minerals of the pyroxene gneisses.

45. It will be seen that according to Professor Judd the corundum and its matrix are both products of alteration of a pre-existing rock, while Mr. Holland, from his studies of the corundum-bearing rocks of Madras, regards the corundum as an original, and in fact the first formed, constituent of the rock in which it occurs. Such discrepancies must be excepted while our knowledge of the chemical reactions, which go on in the interior of the earth, remains as imperfect as it is at present, and there are sufficient differences in the modes of occurrence of the corundum of the Ruby Mines and of Southern India to render it possible, and even probable, that its mode of origin was not the same in both cases.

46. The additions to the library during the past year amount to 2,396 volumes and parts of volumes, of which 1,370 were acquired by presentation and 1,026 by purchase.

Library.

R. D. OLDHAM,

Officiating Director, Geological Survey of India.

CALCUTTA;

The 1st January 1897.

}

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1896.

ADELAIDE.—Geological Survey of South Australia.

„ Royal Society of South Australia.

BALTIMORE.—Johns Hopkins University.

BASEL.—Naturforschende Gesellschaft.

BATAVIA.—Kon. Natuurkundige Vereeniging in Nederl.—Indie.

BELFAST.—Natural History and Philosophical Society.

BERKELEY.—University of California.

BERLIN.—Deutsche Geologische Gesellschaft.

„ K. Preuss. Akad. der Wissenschaften.

„ K. Preuss. Geologische Landesanstalt.

BOMBAY.—Meteorological Department, Government of Bombay.

„ Natural History Society.

„ Royal Asiatic Society.

BORDEAUX.—Société Linnéenne de Bordeaux.

BOSTON.—American Academy of Arts and Sciences.

„ Society of Natural History.

BRESLAU.—Schlesische Gesellschaft für Vaterl. Cultur.

BRISBANE.—Geological Survey of Queensland.

„ Royal Geological Society of Australasia.

„ Royal Society of Queensland.

BRISTOL.—Naturalists' Society.

BRUSSELS.—Académie Royale des Sciences.

„ Musée Roy. d'Hist. Nat. de Belgique.

„ Société Belge de Géographie.

„ Société Royal Malacologique de Belgique.

BUCHAREST.—Museul de Geologia si de Paleontologia.

BUDAPEST.—Kön. Ungarische Geologische Anstalt.

„ Ungarische National Museum.

BUENOS AIRES.—Acad. National de Ciencias.

CAEN.—Société Linnéenne de Normandie.

CALCUTTA.—Agricultural and Horticultural Society of India.

„ Asiatic Society of Bengal.

„ Calcutta University.

„ Editor, *The Indian and Eastern Engineer*.

„ Meteorological Department, Government of India.

„ Survey of India.

CAMBRIDGE.—Philosophical Society.

„ University of Cambridge.

„ Woodwardian Museum.

CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.

CANADA.—Hamilton Association.

CASSEL.—Vereins für Naturkunde zu Kassel.

CINCINNATI.—Society of Natural History.

COPENHAGEN.—Kong. Danske Videnskabernes Selskab.

- DEHRA DUN.—Great Trigonometrical Survey.
 DES MOINES.—Iowa Geological Survey.
 DRESDEN.—K. Min. Geological und Præhist. Museum.
 „ Naturwissenschaftliche Gesells. Isis.
 DUBLIN.—Royal Dublin Society.
 „ „ Irish Academy.
 EDINBURGH.—Geological Society.
 „ Royal Scottish Geographical Society.
 „ „ „ Society of Arts.
 „ „ Society.
 GLASGOW.—Glasgow University.
 „ Philosophical Society.
 GOTHA.—Editor, Petermann's Geog. Mittheilungen.
 GÖTTINGEN.—K. Gesells. der Wissenschaften.
 HALIFAX.—Nova Scotian Institute of Science.
 HALLE.—Naturforschenden Gesellschaft.
 „ Academia Cæsarea Leop.-Carol. Nat. Curiosorum.
 JEFFERSON CITY.—Missouri Geological Survey.
 KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
 LAUSANNE.—Société Vaudoise des Sciences Naturelles.
 LEIPZIG.—Kön. Säch. Gesells. der Wissenschaften.
 „ Vereins für Erdkunde.
 LIÉGE.—Société Geol. de Belgique.
 LISBON.—Section des Travaux Géol. du Portugal.
 LIVERPOOL.—Geological Society.
 LONDON.—British Museum (Natural History).
 „ Geological Society.
 „ Iron and Steel Institute.
 „ Linnean Society of London.
 „ London Library.
 „ Royal Geographical Society.
 „ „ Institution of Great Britain.
 „ „ Society.
 „ Society of Arts.
 „ Zoölogical Society.
 LYONS.—Museum d'Hist. Naturelle.
 MADRAS.—Literary Society.
 MADRID.—Sociedad Geografica de Madrid.
 MAINE.—Portland Society of Natural History.
 MANCHESTER.—Geological Society.
 „ Literary and Philosophical Society.
 MELBOURNE.—Department of Mines and Water-Supply, Victoria.
 „ Royal Society of Victoria.
 MEXICO.—Istituto Geologico de Mexico.
 MILAN.—Società Italiana di Scienze Naturali.
 MOSCOW.—Société Imp. des Naturalistes.
 MUNICH.—Kon. Bayerische Akad. der Wissens.

- NAPLES.—Reale Acad. delle Scienze Fisiche e Matematiche.
- NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
- NEW HAVEN.—Editor, American Journal of Science.
- NEW YORK.—Academy of Sciences.
- OTTAWA.—Geological and Natural History Survey of Canada.
- PARIS.—Department of Mines.
- „ Editor, *Annuaire Géologique Universel*.
- „ *Ministere des Travaux Publics*.
- „ *Museum d'Histoire Naturelle*.
- „ *Société de Géographie*.
- „ „ *Géologique de France*.
- PENZANCE.—Royal Geological Society of Cornwall.
- PHILADELPHIA.—Academy of Natural Sciences.
- „ *American Philosophical Society*.
- „ *Franklin Institute*.
- „ *Wagner Free Institute of Science*.
- PISA.—Societa Toscana di Scienze Naturali.
- RIO-DE-JANEIRO.—Imperial Observatory.
- ROCHESTER.—Geological Society of America.
- ROME.—Reale Accad. dei Lincei.
- „ „ *Comitato Geologico d'Italia*.
- „ *Societa Geologica Italiana*.
- SACRAMENTO.—California State Mining Bureau.
- SALEM.—American Assoc. for the advancement of Science.
- „ *Essex Institute*.
- SAN FRANCISCO.—California Academy of Sciences.
- SPRINGFIELD.—Illinois State Museum of Natural History.
- STOCKHOLM.—Kon. Svenska Vetenskaps Akademien.
- ST. PETERSBURG.—Académie Imperiale des Sciences.
- „ *Comité Géologique*.
- „ *Musée Geol. de l'université Imperiale*.
- „ *Russ. Kaiser. Mineralogische Gesellschaft*.
- STRASBURG.—Strasburg University.
- SYDNEY.—Australian Museum.
- „ *Dept. of Mines and Agric., N. S. Wales*.
- „ *Geological Survey*, „
- „ *Linnean Society*, „
- „ *Royal* „ „
- TOKIO.—Deutsche Gesells. für Natur und Volkerkunde.
- „ *Imperial University of Japan*.
- TORONTO.—Canadian Institute.
- TURIN.—Osservatorio della R. Università.
- „ *Reale Accad. delle Scienze*.
- UPSALA.—Upsala University.
- VENICE.—Reale Istituto Veneto di Scienze.
- VIENNA.—K. Akad. der Wissens.
- „ *K. K. Geog. Gesellschaft*.

VIENNA.—K. K. Geol. Reichsanstalt.

„ K. K. Naturhistorischen Hof.-Museum.

WARSAW.—Inst. Agronomique et forestier.

WASHINGTON.—Smithsonian Institution.

„ U. S. Dept. of Agriculture.

„ „ Geological Survey.

WELLINGTON.—Mining Dept., New Zealand.

„ New Zealand Institute.

YORK.—Yorkshire Philosophical Society.

ZÜRICH.—Naturforschende Gesellschaft.

The Governments of Bengal, Bombay, India, Madras, North-Western Provinces and Oudh, and the Punjab.

The Chief Commissioners of Assam, Burma, and the Central Provinces.

The Resident, Hyderabad.

On some Norite- and associated Basic Dykes and Lava-flows in Southern India. By THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India.*

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I.—INTRODUCTION.

1. In the year 1890, Mr. P. Lake published a short paper describing four specimens of the Cuddapah (Kadapah) lava-flows collected by Dr. W. King.¹ This was intended, I believe, by Mr. Lake to be the first instalment of a detailed description of the Transition contemporaneous traps and their dyke-representatives in South India, in which area he had collected largely from the dykes of Bellary and Anantapur districts and the Raichur Doab, where, under the superintendence of Mr. R. Bruce Foote, he worked over areas partly covered by Transition rocks of the Dharwar system and partly by the older crystallines. Mr. Lake, however, left India towards the end of the same year, and the rocks consequently received no further attention till the commencement of 1892, when I made a tour over the

¹ *Rec. Geol. Surv. India*, Vol. XXIII, p. 259.

southern districts of the Madras Presidency, and, though mainly occupied with a different enquiry, was fortunate enough to obtain opportunities for examining a few of the dykes in the districts of Chingelput, South Arcot, Salem, Coimbatore and the Nilgiris. The specimens collected by myself have been supplemented by a rich collection made by Dr. H. Warth in the South Arcot district, whilst Messrs. Middlemiss and Smith have since been working out more thoroughly the dykes and associated crystalline rocks of the Salem district, and have kindly supplied me with some of their leading types.

All the specimens referred to in this paper are preserved in the Geological Museum, Calcutta, and as this subject will be included in the detailed researches in Salem and Coimbatore now being prosecuted by Messrs. Middlemiss and Smith the registered numbers are in all cases quoted for facility of reference to the type-specimens. I am indebted to Mr. P. Brühl, Professor of Physics in the Civil Engineering College, Sibpur, for the chemical analyses of four types of these dyke-rocks.

II.—GEOLOGICAL AGE OF THE DYKES.

2. Previous to the great outburst of Deccan trap there were at least two main periods of volcanic action in Peninsular India. In the southern portion of the Peninsula these are indicated (1) by the contemporaneous traps of the Dharwar Transition system, and (2) by the Cuddapah lava-flows of later date. So far as the specimens in our collection are concerned the petrological characters of the rocks divide them sharply into two classes. The Dharwar volcanic rocks are essentially hornblende-plagioclase rocks exhibiting marked signs of the changes which accompany the passage of normal diorites into epidiorites and sometimes hornblende-schists. The Cuddapah traps, on the other hand, are remarkably free from such signs of dynamic metamorphism. These are just such differences as might be expected from the known stratigraphical history of Peninsular India. Whilst there is abundant evidence of great crust disturbances in pre-Cuddapah times, the Indian Peninsula since that epoch has been remarkably free from disturbances by earth movements, and, as one result, the pyroxenic igneous rocks, which so readily yield to dynamic action, have been preserved with remarkable freshness.

3. The distinction between post-Cuddapah and pre-Cuddapah lava-flows might be expected to find similar expression in the dyke-representatives of these volcanic rocks; and, whilst fully recognising the danger of correlation from petrological characters alone, it must be accepted in the present instance as the only evidence of a positive character. The age of a dyke, whose connection with a known lava-flow is not manifest, can seldom be determined within very narrow limits, and even then the limit on the younger side generally depends on purely negative evidence. In the South of India the great series of basic dykes which break through the old crystalline rocks, and sometimes through the Dharwars, have, partly from their being grouped around the Cuddapah area,¹ and partly from their absence from the younger Karnul strata, been generally regarded as the dyke-representatives of the great lava-flows in the Chey-air group of the Cuddapah system. It is interesting to find that this evidence, which alone would be very unsatisfactory, receives confirm-

¹ Cf. *Manual Geology of India*, 2nd Ed., p. 40.

ation by comparison of the petrological characters of the dykes and the lava-flows, which agree not only in the ordinary characters, but in exhibiting certain peculiar features rarely exhibited in other areas.

III.—CLASSIFICATION OF THE ROCKS.

4. So far as represented by specimens in the Calcutta collection, the dyke-rocks of South India and the lava-flows in the Cuddapahs, their supposed volcanic representatives, belong to three main groups, which pass into one another by a series of transitional types too gradual to permit of any definite line of demarcation. For convenience of description they are classified as follows:—

- (1) OLIVINE-NORITE GROUP, in which olivine, enstatite, augite and a basic plagioclase-felspar are essential constituents, the plagioclase being always the latest constituent to complete its consolidation and enveloping all its associates. Small quantities of biotite are invariably present.
- (2) AUGITE-NORITE GROUP, distinguished from group 1 by the absence of olivine, and by an increase in the amount of augite. The plagioclase is still the latest constituent to complete its consolidation. Biotite in small quantities is generally present.
- (3) AUGITE-DIORITE GROUP, in which the enstatite is either small in quantity or absent altogether. Biotite at the same time disappears, and the order of consolidation of the constituents is modified, giving rise, by the later comparative consolidation of the augite, to a tendency to the production of ophitic structure. The members of this group are invariably characterised by the presence of micropegmatitic (micrographic) intergrowths of quartz and felspar, which are regarded as primary in origin, and sometimes contain potash-felspar.

5. The following table gives the order of consolidation of the essential constituents in each group:

1.	2.	3.
Olivine-norite group.	Augite-norite group.	Augite-diorite group.
Olivine.	...	...
Enstatite.	Enstatite.	...
Augite.	Augite.	Augite.
Plagioclase.	Plagioclase.	Plagioclase.
...	...	Micropegmatite.

Hemicrystalline representatives.

6. Each group is represented by *microcrystalline* and *hemicrystalline* types occurring either as thin veins, or as selvages to larger masses.

Group 1 is represented (1) by a rock having a black cryptocrystalline matrix with phenocrysts of *olivine only* and (2) by a micro-variolitic tachylyte.¹

Group 2 is represented by a micro-crystalline matrix of augite, felspar and magnetite with some glass, in which there are phenocrysts of *enstatite only*.

Group 3 is represented by a microcrystalline matrix of augite, felspar and magnetite with phenocrysts of augite and labradorite.

The hemicrystalline varieties of groups 1 and 2 are thus related to the comparatively rare magma-basalts (*limburgites*) in which the essential phenocrysts are olivine and augite; but as the Madras rocks show in one case only olivine and in other cases only enstatite, they differ, as far as I am aware, from any previously-described type; but, until their field-relations have been more precisely traced out, I consider it inadvisable to distinguish them by special names.

The chemical analyses of these rocks by Mr. Brühl (see paragraphs 10, 22, 49 and 71) show that they vary in silica percentage from 43.77 to 53.05; but the variation in silica percentage is by no means as uniform as that of the magnesia which varies from 21.21 per cent. in the Jootoor lava-flow to 6.48 in the augite-diorite dykes.

(1) OLIVINE-NORITE GROUP.

(a.) *Holocrystalline varieties.*

7. Amongst the great lava-flows of the Chey-air beds described in his memoir "On the Kadapah and Karnul formations in the Madras Presidency," Dr. W. King has referred to the Jootoor flow on the left bank of the Pennair river as an olivine-bearing rock.² Mr. P. Lake, in a paper on "The Basic Eruptive Rocks of the Kadapah Area," described the microscopic characters of this rock as an olivine-dolcrite or olivine-gabbro, composed chiefly of olivine, augite, and plagioclase felspar, "with opacite" and a little mica.³

¹ Since the above was written, Mr. C. S. Middlemiss has called my attention to a hemicrystalline representative of this class collected by him at a place 1½ miles. E.N.E. of Kanivenhalli, near Palakod, Salem district (No. 10,262). The rock occurs as a dyke only 8 inches wide, cutting obliquely across the gneiss. It is very compact and dark-grey in colour, weathering into round boulders. Microscopic examination shows it to be an *enstatite magma-basalt* (*enstatite limburgite*); that is, a magma-basalt in which, besides augite and olivine, there are phenocrysts of enstatite; indeed enstatite is the most abundant member of the phenocrystalline constituents. The characters of the mineral are precisely those of the enstatite occurring in the peculiar "norite-felsite" of Eriyūr (para. 48) and the likeness is rendered still more striking by the shells of augite in which the enstatites are so remarkably encased. The groundmass, composed of minute augites, skeleton crystals of magnetite and small quantities of possibly embryonic felspars, also recalls the finest-grained varieties of the Eriyūr rock; but the fine phenocrysts of the peculiar brown olivine found in the rocks from Singapuram (para. 25), Vitlapuram (para. 33) and Coonoor (para. 36) connect this interesting rock with the class of olivine-norites. Besides being of value as a means of additional evidence showing the relationship between the olivine-norites and augite-norites forming these dykes, this rock is interesting as the first-recorded magma-basalt in India, and is one which, on account of its display of enstatite phenocrysts, is a peculiar form of its class.

² *Mem. Geol. Surv. Ind.*, Vol. VIII, p. 196 (1872).

³ *Rec. Geol. Surv. Ind.*, Vol. XXIII, p. 259 (1890).

8. Further examination of the rock, however, shows according to my determination that the predominating pyroxenic constituent is enstatite, whilst the plagioclasic felspar, which is very small in quantity, occurs as the last-formed constituent growing ophitically around its associates, olivine, enstatite and augite. In addition to these facts, there are certain peculiar structures which strongly recall those exhibited in many of the rocks occurring as dykes amongst the crystalline rocks of South India, and still more strikingly a handsome rock recently collected by my colleague Mr. P. N. Datta in South Rewa (Rock number 10,588).

As the last-named rock is the most coarsely-crystallized, and the freshest specimen in the group now under consideration, it may be conveniently selected as the type for detailed description.

9. The rock occurs, according to Mr. Datta, as a dyke in mica-gneiss on the Sone River, one mile south-west of Kaithaha, near Saria, South Rewa (lat. $24^{\circ} 11' 5''$, long. $81^{\circ} 23'$). In hand-specimen it is a dark-coloured, tough rock, with flakes of brown mica, granules of olivine and cleavage-plates of felspar distinctly visible to the naked eye. Its specific gravity is 3.47.

10. A chemical analysis (*cf.* para. 22) made by Mr. Paul Brühl, Professor of Physics in the Civil Engineering College, Sibpur, gave the following results:—

Si O ₂	.	.	.	.	.	.	.	.	.	.	50.45
Ti O ₂	.	.	.	.	.	.	.	.	.	.	0.63
Al ₂ O ₃	(with a small quantity of P ₂ O ₅ and Mn ₂ O ₄)	.	.	.	.	.	.	.	.	.	6.50
Fe ₂ O ₃	.	.	.	.	.	.	.	.	.	.	2.49
Fe O	.	.	.	.	.	.	.	.	.	.	8.38
Ca O	.	.	.	.	.	.	.	.	.	.	7.82
Mg O	.	.	.	.	.	.	.	.	.	.	19.02
H ₂ O	.	.	.	.	.	.	.	.	.	.	0.97
Alkalies	.	.	.	.	.	.	.	.	.	.	undetermined.

11. Under the microscope the rock is seen to be a holocrystalline aggregate of the following minerals, whose names are given approximately in the order of their formation:—

Primary:—

Apatite.
Olivine.
Enstatite and Augite.
Biotite.
Plagioclase.

Secondary:—

Reaction rims of actinolite and enstatite.
Biotite.
Magnetite.

12. *Apatite*.—Occurs only in small quantities, with the usual needle-shaped prisms cracked transversely, showing low double refraction, and included by all the other constituents except olivine.

13. *Olivine* occurs in large crystals, generally with their idiomorphic outlines well displayed. They are cracked in the characteristically irregular fashion with the development of much dusty magnetite. Besides innumerable, small, rod-like inclusions arranged in parallel lines, the dendritic inclusions which have been described by Professor Judd¹ as one of the results of the schillerization of this mineral are

¹ *Quart. Journ. Geol. Soc.*, Vol. XLI, p. 381 and plate XII, figs. 2-7. (1885).

very beautifully displayed in this mineral, and are arranged parallel to the macro-pinacoid, as I have shown to be the case in the olivines of a mica-hypersthene peridotite occurring in the Mámbhúm district of Bengal.¹ This is very clearly demonstrated in one of the sections (No. 2125) evidently cut parallel to the basal plane, and showing the cut edges of the dendritic plates lying at right angles to the brachy-pinacoidal cleavage cracks. The quartz wedge inserted parallel to the edges of the inclusions shows well-marked 'thinning' thus indicating the axis of maximum elasticity & parallel to the macro-diagonal.

14. But the most striking feature in connection with these olivines is the occurrence of very well defined and broad "reaction-rims" between this mineral and the felspar, similar to those which have so frequently been recorded in basic and ultra-basic rocks. The reaction-rims are composed of an external layer of feathery green actinolite abutting against the felspar, considerably wider, as a rule, than the inner zone of granular, colourless mineral, which exhibits a double refraction distinctly lower than that of the actinolite.

The colourless mineral in this case is regarded as enstatite, because it has been found in several instances in crystallographic continuity with larger adjoining original crystals of that mineral. It is frequently found also that both the augites and the enstatites are separated from the olivine by a very narrow zone of this colourless mineral, which sometimes exhibits crystallographic continuity with the enstatite, appearing thus as a secondary extension of the mineral, like the well known secondary enlargements of quartz, felspar, augite, hornblende and mica (Fig. 1).

15. The question of the origin of these so-called reaction-rims which so frequently characterise the olivines of very basic rocks has frequently been discussed, and very different explanations have been offered, both as to the precise nature of the reaction products and the mode of their formation, which is not a surprising result, seeing both the compositions of the reacting minerals, as well as the physical conditions of formation must, within certain limits, be variable.² Although the present instances do not appear to offer conclusive evidence, the general assemblage of facts point, in my opinion, to the origin of the rim as the result of the reaction between the olivine and a more siliceous mineral, felspar, under the particular physical conditions which are attended with various other structural characters—primary and secondary—that distinguish plutonic rocks from lavas. In this case the reaction-rims occur in a rock which shows the schillerization and other phenomena characteristic of deep-seated rock-masses, whilst all these structures are absent in the Jootoor lava, which mineralogically is the very evident equivalent of this rock. But in the lava a pilitic decomposition of the olivine has taken place (*vide infra* para. 23) which is certainly secondary and confined by the original limits of the olivine crystals. The evidence points also to the formation of the pilitite with the aid of compounds derived from the adjoining decomposing felspar.

16. That the fibrous and granular borders are real reaction-rims is therefore

¹ *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 144 (1894).

² For summary of results see J. F. Kemp "Gabbros on the western shore of Lake Champlain" [*Bull. Geol. Soc. of America*, Vol. V, p. 221 (1894)], and a later paper in the same year by W. D. Mathew on "The intrusive rocks near St. John, New Brunswick" [*Trans. N. Y. Acad. Sci.*, Vol. XIII, p. 198, (1894)]. In the latter paper the author points out the continuity of the granular inner zone with larger hypersthene crystals and regards it as an original formation.

supported indirectly by the peculiar nature of the secondary decomposition of the olivine in the lavas; but the question as to whether the reaction-rims are formed during the consolidation of the rock—as the late G. H. Williams supposed to be the case in the very similar and now well-known occurrence near Peekskill, N. Y.—¹ or subsequently, is not determined by this evidence, as there are so many instances to show that the structures produced rapidly during the primary consolidation of a molten magma can be closely imitated by those produced more slowly during secondary changes subsequently induced in the consolidated rock.

17. The *pyroxenes* are nearly all colourless, the rhombic forms exhibiting a faint pleochroism only in thick sections. The most abundant form is enstatite, which exhibits in part at least its proper crystal outlines, with characteristic cleavage and optical characters.

18. The most remarkable feature in connection with the pyroxenes is the development of a series of minute and vermiform canals, arranged in approximately parallel directions and giving an appearance which at first sight resembles the microperthitic structures of feldspars. Sometimes patches of such structures are seen spreading out like a disease in the pyroxene, and changing its polarization colours to a lower order. Isolated patches sometimes show simultaneous extinction, and at other times the patches growing out from different points in a pyroxene crystal meet in irregular lines and divide the crystal into a mosaic between crossed Nicols. This may occur either in a rhombic or a monoclinic pyroxene, but the ragged portions exhibit colours of too high an order for the rhombic form. Although I feel unable to account satisfactorily for this phenomenon, the microscopic intergrowth of two pyroxenes seems to meet all the requirements of the case more perfectly than any other explanation that has occurred to me. Whatever the structure may be due to, it is found again in just as striking a manner, though less frequently, in the Jootoor trap-flow, whose characters generally so closely repeat the microscopic structures and mineralogical composition of this rock.² Like all the primary constituents of this rock, the pyroxenes are schillerized, and more strikingly so in the monoclinic than in the rhombic forms.

19. The *felspar*, which is the least abundant and last formed amongst the primary constituents, is twinned in broad lamellæ and exhibits wide extinction angles approaching those of bytownite. It is often darkened by fine dusty inclusions and the high powers show numerous minute needles and plates arranged in parallel lines, as is commonly the case with schillerized plagioclase.

20. *Biotite* occurs as minute plates intergrown with the enstatite in a way which suggests its derivation from the latter mineral. It occurs also in larger bundles which exhibit a strong pleochroism and contain numerous dark-brown needles crossing one another as usual at angles of 60°. The biotites are certainly of later

¹ *Amer. Journ. Sci.*, 3rd ser., Vol. XXXI, p. 35 (1886).

² This structure resembles in many respects those which have been described and figured by Prof. Sollas in the gabbro of Barnavave, Carlingford, and which he ascribed to an intergrowth of diallage and rhombic pyroxene which are intergrown so that the face 010 of one lies parallel to the face 100 of the other (*Trans. Roy. Irish Acad.*, Vol. XXX (1894), p. 424; plate XXVI, figs. 4 and 6). But in the rock under description the intergrown pyroxenes appear to be invariably both monoclinic, though intergrowths of a different nature of both monoclinic and rhombic pyroxenes are also found in this rock.

formation than the pyroxenes which they frequently partly envelope, but are, however, older than the feldspars.

21. A rock having precisely similar mineralogical composition, and equally fresh, has been collected by Mr. R. Bruce Foote at Kudatami in the Bellary district, No. 8,767. The order of consolidation of the constituents is precisely the same also as in the Rewa rock; but there is no trace of a reaction-rim between the olivines and feldspars, and in this rock the olivines are the only constituents showing signs of schillerization. These facts so far as they go, therefore, are in agreement with the suggestion that schillerization and the formation of reaction-rims imply in some respects at least similarity of physical conditions (*supra*, para. 15). Professor Judd¹ has included the formation of reaction-rims amongst the instances of secondary changes induced in rocks under the combined influence of pressure and high temperature, and the facts revealed by the examples under consideration are, so far as they go, in agreement with such a conclusion.

22. On comparing this rock with the *Jootoor trap-flow* (No. 9,793), we find the differences are almost entirely due to a more fine-grained crystallization and the absence of schillerization phenomena in the latter rock. These are just such differences as might be expected between a plutonic rock and its volcanic representative. The essential constituents and the order of their formation—olivine, colourless enstatite and augite, biotite and plagioclase—are identical. The proportion of feldspar, however, is smaller, and olivine is more abundant, but the minerals are apparently of the same species and even the peculiar micrographic structure shown by the pyroxene of the Rewa rock is exhibited also, though less frequently, in the Jootoor lava.

These differences in the proportions of mineral constituents bringing the rock into close relations with the saxonites (harzburgites), appear in the chemical analysis made by Mr. P. Brühl, which gave the following results (*cf.* para. 10).

Si O ₂	.	.	.	43.77
Ti O ₂	.	.	.	0.74
Al ₂ O ₃	(and P ₂ O ₅)	.	.	7.53
Fe ₂ O ₃	.	.	.	4.64
Mn ₂ O ₃	.	.	.	0.74
Fe O	.	.	.	7.91
Ca O	.	.	.	5.58
Mg O	.	.	.	21.21
H ₂ O	.	.	.	3.15
Alkalies	.	.	.	undetermined.

23. The original outlines of the olivines in this rock are marked by lines of opaque black granules, between which and the core of undeveloped olivine there is a zone of variable width of a fibrous mineral exhibiting low double refraction and forming generally a confused felt. As this zone of fibrous mineral is well-developed at the contact of the olivine with feldspar, and is practically absent where the former mineral abuts against either of the pyroxenic constituents, it is evident that proximity to the feldspar facilitates the formation of the fibrous mineral. The lines of opaque granules, from their rectilinear disposition, evidently mark the original outline of the olivine crystals;

¹ *Journ. Chem. Soc.*, May 1890.

and thus the fibrous mineral must have been formed entirely at the expense of the olivine.

24. These zones are, therefore, secondary in origin, and as they do not extend beyond the limits of the original olivine-crystals, they cannot be regarded as the equivalents of the reaction-rims so beautifully displayed by the Rewa rock. The fibrous area is very variable in width, sometimes extending to the centres of even large crystals of olivine. The features exhibited agree with those of a fibrous form of amphibole and are probably similar to the felt of amphibole needles pseudomorphous after olivine to which Becke has given the name *pilite*.¹ As the felspars are often considerably kaolinized, it is not unnatural that this change to amphibole (*pilite*) should be more marked where the olivine is bordered by the mineral whose decomposition can supply the requisite amount of lime and silica.

25. Amongst the *dykes* occurring in the Madras Presidency the nearest approach to the rocks of the class under consideration occurs
 Olivine-bearing dykes of Madras (Salem district). near the quartz-magnetite beds of Singapuram, Ahtur taluk, Salem district (No. 9,398). This rock is black in hand-specimen even to the felspars, which show slight "lustre mottling." It has a specific gravity of 3.12. Under the microscope it is seen to be perfectly holocrystalline in structure and is composed of olivine, enstatite (bronzite and hypersthene), augite, biotite and plagioclase in order of formation, with granules of pyrite and dusty magnetite.

26. The *olivine* is about equal to the pyroxene in quantity; it often shows its crystal outlines, but is rarely intergrown with the enstatite to produce a very imperfect graphic structure. It is cracked in a characteristically irregular fashion, with separation of dusty magnetite and very rarely shows the serpentinous hydration. Reaction rims between it and the felspar occasionally occur, but are generally very narrow though very well-defined, and with the same arrangement of colourless mineral and actinolite as seen in the Rewa rock.

27. The most characteristic feature of the olivine, however, is the large quantity of minute inclusions—dust and rods—arranged in definite crystallographic planes and giving the sections a brown or dark brown colour when seen with low powers, and what, on rapid revolution of the polariser, appears to resemble the faint pleochroism of some brown augites, but which is probably only a diffraction effect. This character is true of the olivines in all the dyke-rocks which I have mentioned below and which I propose to include in this group. The general characters exhibited by the sections of this mineral leave little doubt as to the nature of the species, and that little doubt is completely removed by the occurrence in this rock of the dendritic inclusions such as are so plainly displayed in the olivines of the Rewa rock (slide 1424).

28. The *enstatites* show a distinct pleochroism, sometimes approaching in intensity that of the hypersthene which are constant throughout the pyroxene granulites of this area.

29. The *augite* is perfectly colourless in thin section, is feebly schillerized and frequently developed between the felspar plates like little intrusive sheets and fingers, which, when cut across, show several isolated patches having simultaneous extinction.

¹ *Tschermak's min. und petr. Mitt.*, Vol. V, p. 163 (1883).

30. The *biotite* is frequently associated with coarse granules of opaque iron-ores, shows the same kind of pleochroism, and occurs in apparently the same proportions as already described for the Rewa rock and the Jootoor lava.

31. The *felspar* is more abundant and of a less basic type than that playing a similar rôle in the Rewa rock. The crystals are light-brown in section on account of innumerable minute inclusions, but the colour shades off towards the periphery of the crystals which are generally colourless. Polarized light shows also that there is a zoning due to gradual change in composition in the later-formed layers. Minute acicular inclusions, like actinolite-needles, are often seen in patches of the colourless portion of the felspar, where there appears to have been a small amount of decomposition with sometimes formation of presumably secondary quartz.

32. *Magnetite* in fair quantity occurs in all the other minerals, either as lumps, which are possibly original, or as fine dust, which is of secondary origin. Occasional lumps of *pyrite* are seen in hand-specimen.

33. For the next stage, showing a less basic tendency, a rock collected by Dr. H. Warth at one mile west of Vitlapuram in South Arcot district, may be taken as a type (No. 9,811). This rock occurs as a dyke in the pyroxene-granulites, most of which in that area contain large quantities of quartz, and are distinctly acid in silica-percentage.

34. The dyke-rock is black in hand-specimen, and has a specific gravity of 3.03 (Warth). Under the microscope, it shows the same peculiar dark-brown olivine, colourless enstatite and augite, small quantities of biotite, magnetite and pyrite, and the same brown, zoned plagioclase with colourless borders, forming the ground-mass as in the Singapuram rock. But in the Vitlapuram rock there is a distinctly smaller quantity of olivine, and, at the same time, an increase in the size and frequency of the colourless patches, which shows the signs of secondary decomposition referred to before, but in this case calcite as well as quartz occurs amongst the secondary minerals.

35. The Singapuram rock occurs at a place which is about equidistant from Vitlapuram near the Coromandel coast and Coonoor in the Nilgiri Hills (a total horizontal distance of about 200 miles), where I have also found dykes of unmistakably the same rock intrusive in the pyroxene-granulite series which make up the main mass of that range.

36. The dykes of Coonoor are especially interesting on account of the variations they show from the well-crystallized types in the wider dykes to the hemicrystalline and even glassy tachylytic types which occur in the narrower veins and on the selvages of larger masses, but in all of them the peculiar brown olivine occurs, and the same order of crystallization of the pyroxenes, biotite and light-brown plagioclase-felspar is preserved. Although the plagioclase crystals are seen to be the last-formed from the way in which they are moulded on to all the other constituents, their crystallization, having commenced from so many centres during the comparatively rapid consolidation of the final stages, has not resulted in their perfect ophitic development, as is the case with the coarser-grained types described from the other localities above.

37. In the very fine-grained varieties forming narrow veins in the pyroxene-granulites, the microscope shows olivine, pyroxene and felspar as phenocrysts in a microcrystalline matrix of pyroxene, biotite, felspar and magnetite, and the pheno-

crysts sometimes gather in groups giving rise to the structure to which Prof. Judd has given the name *glomeroporphyritic*.¹ This sometimes takes the peculiar form of large olivine crystals surrounded by a zone of colourless granular pyroxene (slide 1599). In the narrow veins the long crystals of felspar and enstatite are frequently arranged parallel to the sides of the dyke, a feature commonly exhibited by porphyritic crystals in narrow dyke-rocks.

38. As the edge of the dyke is approached the matrix becomes finer in grain, until, at the selvages, the rock shows a vitreous matrix with
 Variolitic selvages. tufted aggregates of microlites, attempting an imperfect spherulitic or variolitic structure. Glomeroporphyritic aggregates of olivine and enstatite occur as in the types described above.

(b.) *Exceptional hemicrystalline varieties of olivine-norites.*

39. An exceptional type of the hemicrystalline varieties which presumably belongs to this class of rock occurs as a narrow vein only half an inch wide running through a hornblende-norite collected by the late Mr. C. Æ. Oldham near Poorsy, N. N. W. of Wandiwash.

This rock consists of a matrix blackened by magnetite-dust, and studded with
 Magma-basalt with- excessively minute, colourless microlites, in which occur
 out augite.² well-shaped phenocrysts of olivine reaching 3 mm. in length and cracked in the usually irregular fashion of olivine with slight development of yellow serpentine.

40. The *olivines* show a very striking zonal structure by the alternations of light-brown and colourless bands, which however are sometimes quite irregular in arrangement. The light-brown patches display a very faint pleochroism, which is only noticeably marked in basal sections, and shows an absorption in those sections of $\lambda > \lambda$ (slide No. 2027). In those sections also minute rod-like inclusions are arranged at right angles to the brachypinacoidal cleavage-cracks and evidently are the results of the normal schillerization of the mineral (*vide supra*, para. 13).

The last stages in the growth of the crystal are marked by layers of opaque granules, and the colourless zone separating this layer of granules from the opaque matrix is frequently decomposed and pilitic, in which cases the layer of opaque granules has generally a ragged inner border due to extension inwards of the decomposition, accompanied by the usual separation of dusty magnetite. The mineral is decomposed by strong hot hydrochloric acid with formation of gelatinous silica. The crystals are frequently corroded by the magma (Plate I, fig. 3).

41. The occurrence of olivine so well-developed and as the only phenocrystalline constituent makes this a most unusual type of rock. *Magma-basalts* (*limburgites*) with augite as well as olivine phenocrysts have been described from various places, and, to a less extent, *augitites* with augite only developed; but I can recall no case exactly parallel to this in which well-formed olivine in a black glassy matrix is the only phenocryst.

(c.) *Association of Olivine-norites with "Pyroxene-granulites."*

42. If, as seems very likely from their close resemblance to the Jootoor lava-flow, the dyke-rocks described above are the plutonic equivalents of the volcanic

¹ *Quart. Journ. Geol. Soc.*, Vol. XLII, p. 71 (1886).

² Mr. C. S. Middlemiss has, since the above was written, called my attention to a fine example of an enstatite magma-basalt amongst these dykes. For its description see para. 6, foot-note.

rocks of the Cuddapah system, the time of their intrusion is fixed with regard to the Indian stratigraphical succession.

43. That these rocks are true intrusions and not segregation veins is very evident from their occurrence as vitreous forms near the selvages of larger dykes and in the smaller veins, with fluidal structures also. As they break across the pyroxene-granulite series of the Madras Presidency, showing no signs of the foliation which the latter rocks have suffered, their intrusion must have occurred since the foliation of those rocks. And yet there remains the remarkable fact that rhombic pyroxene, which is the one constant constituent of the pyroxene-granulite group, is present in all these dykes which are so frequently associated with them. That this is a mere accident is of course quite possible; still, the association is a circumstance worthy of record, and I give it as a mere suggestion that the magma from which these intrusions and lavas have been derived might have been obtained by the local re-fusion of the pyroxene-granulite series.

44. The association of olivine-norites with the ordinary members of this group has been recorded in different parts of the world; but the cases presenting the nearest approach to the instance under consideration are the rocks of the Cortlandt series of New York, in which the late G. H. Williams¹ described types varying from peridotites with little or no felspar to normal norites, and those described by Dr. F. H. Hatch² from Madagascar, where olivine-norites are associated with ordinary types which are remarkably similar to those of the Madras Presidency, and are probably simply a portion of the same great crystalline mass—portions of the old Gondwana continent still remaining above the sea-level.

The chemical analyses by Mr. Brühl of four different Madras types show that alumina is comparatively low amongst the sesquioxides, whilst magnesia and ferrous oxide are unusually abundant amongst the protoxides, results which might be expected where the ordinary augites are so largely replaced by enstatites amongst the ferromagnesian silicates. It will be interesting to compare these analyses with those now being made of the various types of the pyroxene-granulite series of the Madras Presidency.

(2) AUGITE-NORITE GROUP.

(a.) *Holocrystalline varieties.*³

45. As examples of dykes linking the characters of the olivine and enstatite-bearing group with those in which augite predominates, may be mentioned those discovered near Rayakotta, Maharajgadi, and Krishnagiri in the Salem district, by my colleagues Messrs. Middlemiss and Smith, who have kindly sent me specimens and descriptions of the field-relations and microscopic characters of the rocks.

46. The most striking of these occurs as a dyke 100 yards wide running east and west in the gneiss, 5 miles south of Vepanapalli, on the road north of Krishnagiri.⁴ It has a specific gravity of 3.08 and is composed, according to Mr. Smith, of idiomorphic crystals of hypersthene, a smaller quantity of augite, wrapped around

¹ *Amer. Journ. Sci.*, 3rd ser., Vol. XXXI (1886), p. 26; Vol. XXXIII (1887), pp. 135—191.

² *Quart. Journ. Geol. Soc.*, Vol. XLV (1889), p. 342. Cf. R. Baron, *ibid.*, Vol. LI (1895), p. 59.

³ For varieties approaching pyroxenites by diminution of felspar see para. 56.

⁴ Field number (A) 11th February 1896.

by large ophitic-like plates of plagioclase. As accessories, in part secondary in origin, are biotite, hornblende and magnetite-granules. In the specimen sent I have also found crystals of clear quartz, which, being associated with the kaolinized portions of the felspar, are possibly of secondary origin. This rock differs from the previously-described group; therefore, only in the absence of olivine, whilst the presence of a rhombic as well as monoclinic pyroxene, and the order of consolidation of the constituents make it a link on the basic (olivine-bearing) side.

47. A second link is represented by some small dykes in the gneiss south of Bolconda on the Salagiri-Krishnagiri road in the same district.¹

In this rock Mr. Smith finds the hypersthene and augite to be represented in about equal quantities, and the specimen sent shows some interesting intergrowths of the two minerals.

(b.) *Exceptional hemicrystalline variation of Augite-norites.*

48. The rocks of this transitional group are represented also by hemicrystalline varieties which are of a most unusual type. Specimens of these have been collected by Dr. Warth near Eriyur in the South Arcot District (No. 9,782).

They are tough, black, tachylytic-looking rocks, with small glassy-looking crystals of a colourless mineral, which, under the microscope, are seen to be enstatite, lying in a fine-grained, black matrix, which is probably in part vitreous. This rock corresponds in this group to the Poorsy rock in the olivine-norite group and to the augites which have been described in various parts of the world. But both this and the olivine-bearing rock of Poorsy are, so far as I am aware, type hitherto undescribed.

49. It occurs, according to Dr. Warth, as a dyke four feet wide running east-north-east and west-south-west in the pyroxene-granulites, and specimens gave an average specific gravity of 3.09.

An analysis of this peculiar rock by Mr. P. Brühl gave the following results:—

Si O ₂	.	.	.	53.05
Ti O ₂	.	.	.	1.77
P ₂ O ₅	.	.	.	0.09
Al ₂ O ₃	.	.	.	8.91
Fe ₂ O ₃	.	.	.	3.26
Mn ₂ O ₃	.	.	.	0.09
Fe O	.	.	.	9.52
Ca O	.	.	.	6.76
Mg O	.	.	.	14.42
K ₂ O	.	.	.	0.48
Na ₂ O	.	.	.	0.66
H ₂ O	.	.	.	0.65
				99.66

50. Under the microscope well-shaped crystals of *enstatite* attaining 2 mm. in length form the only phenocrysts. They are perfectly fresh and colourless, and from the shapes of the sections which show the typical cleavage of pyroxene, exhibit combinations

The Enstatite phenocrysts.

¹ Field number (A) 6th February 1896.

of the two pinacoids with the prism, giving the eight-sided shapes so commonly displayed by horizontal sections of pyroxenes. They exhibit a tendency to aggregate in groups of several individuals. The double refraction is low, and the two optic axes can be distinctly observed in basal sections examined by convergent polarized light. The crystals are unattacked by hot hydrochloric acid.

51. The groundmass of the rocks consists of minute crystals of colourless augite wrapped around by tufted microlites of presumably felspar, with a black opaque glass (?) filling the interspaces.

52. The colourless crystals, though so minute, are well-defined, and their examination with $\frac{1}{8}$ -inch objective leaves no doubt about their being augite. They exhibit a tendency to form long

Augite microlites. crystals with the prismatic faces well developed, and are often very clearly twinned according to the usual law of augite. Well defined cleavage-cracks are displayed by the larger individuals. Groups of apparently isolated crystals often show simultaneous extinction. Their strong double refraction and wide extinction angles serve to distinguish them from the large phenocrysts of the rhombic pyroxene.

53. The tendency they exhibit of growing around the phenocrysts of enstatite is a feature of special interest on account of its bearing on the frequent intergrowths of these two minerals, which are described below (para. 60). In most cases the augite sections are seen like two long lath-shaped crystals on either side of the vertical sections of enstatite, but instead of being sections of independent crystals they are found invariably to exhibit simultaneous extinction. As the lath-shaped crystals bordering the sides of the enstatites are frequently found in optical continuity with a narrow band around the ends of the latter mineral, there is no doubt that the enstatite is encased in a thin shell of augite, which belongs to one crystal and though in this rock is invariably so thin, it represents the beginnings of the large crystals described below (para. 60). In addition to this casing of the enstatite in augite, which is quite common, numerous cases occur in which minute pieces of the latter mineral are found scattered through the phenocrysts of the former, and all show by simultaneous extinctions the crystallographic continuity of these included fragments of augite with the thin casing of the same mineral, and thus we have the beginnings of the complicated intergrowths of the two forms of pyroxene so frequently recorded in the basic rocks.

54. The colourless tufted microlites, which, with minute opaque black granules, constitute the rest of the groundmass, belong presumably to the felspar which plays the rôle of groundmass in the holocrystalline types of these rocks. They show weak double refraction and extinction angles of about 10° measured from the long axis of the microlite, and binary twins could be distinctly observed. In this rock therefore we have the order of consolidation the same as that shown in the holocrystalline forms—enstatite, augite and felspar.

As this rock changes considerably in grain even in the same hand-specimen it would be interesting to trace out the characters of the dyke more precisely. But, so far as the specimens collected by Dr. Warth go, the coarser-grained portions show a very striking approach in their characters to those of the more holocrystalline type found by Mr. Middlemiss in the Salem district and described below (para. 56).

(c.) Volcanic representatives of the Augite-norites.

55. As far as can be determined with the small amount of material available for comparison, the Palamodu trap-flow (No. 9,794) of the Cuddapahs appears to correspond in mineralogical character to the dyke-rocks included in this group. Mr. Lake¹ has described this rock, calling attention, amongst other results of its secondary decomposition, to the presence in it of bastite, which he regards as the result of the alteration of the augite. From the way in which this mineral is associated with the augite I should suggest that it is the altered representative of the enstatite which, in the fresher dyke-rocks, shows a precisely similar relation to the augite, and is unquestionably an original constituent. The alteration of the less stable enstatite which shows such ragged irregular junction with the augite in the fresh rock might very well give rise to the impression that it is the result of change extending outwards from the centres of the latter mineral. It should be remarked, however, that the ophitic structure shown so strongly in this rock distinguishes it from the members of the augite-norite group in which the pyroxene shows such a tendency to crystallize before the felspar. I do not, consequently, put much reliance on this correlation. It is unfortunate that the great trap-flows of the Cuddapahs, which evidently include an interesting variety of rocks, should be represented by so few specimens, and until further collections are made the correlation of the dykes with the lava-flows must remain in its present rather unsatisfactory state.

(d.) Varieties approaching Pyroxenites.

56. It is frequently found that in the foregoing two groups the rocks locally approach the ultra-basic group by diminution in the proportion of felspar. In the olivine-bearing group, for instance, the rocks sometimes approach saxonites (harzburgites) in composition, and in this group pyroxenites. An interesting example of the latter modification has been found by Mr. Middlemiss two miles from Thalli on the Hosur road, Salem district.² Mr. Middlemiss describes the rock as a dark, greenish-grey, medium grained rock with a specific gravity of 3.11. Under the microscope it is composed of enstatite in large idiomorphic crystals, augite in smaller granular crystals, often grown around the enstatite, and plagioclase in long slender blades arranged in branching and net-like fasciculæ or tufts. These sometimes run around, and sometimes end abruptly against, the pyroxenes, appearing again on the other side. Black iron-ores and a green mineral in small quantity appear filling in spaces between branching felspars. Mr. Middlemiss has kindly sent me a specimen of this rock, and, as his description would lead one to expect, the rock is just such an one as might be expected from the more perfect crystallization of that which I have just described as a hemicrystalline type of this group (paras. 48—54).

57. A still nearer approach to the purer pyroxene-rock, and a type much coarser in grain, was obtained in the year 1889 by Mr. R. Bruce Foote south of Nilgunda, Harapanhalli taluk, Bellary district (No. 8,823). It is a tough, dark grey, even-grained rock with a specific gravity of 3.22. Under the microscope it is

¹ *Rec. Geol. Surv. Ind.*, Vol. XXIII (1890), p. 260.

² Field number (†) 12-2-96.

seen to be composed almost wholly of pale *pyroxene*, with the interspaces filled in with a *plagioclase felspar* approaching anorthite in composition, and showing by its extinction a crystallographic continuity in isolated patches over very large areas. The pyroxene is partly pale hypersthene, showing a faint pleochroism and frequently idiomorphic outlines, with a very pale green augite growing around it. The rhombic pyroxene appears to be well in excess of the monoclinic form. Occasional granules of opaque iron-ores occur sometimes associated with biotite. No trace of olivine has been discovered. I have frequently found pyroxenites composed essentially of hypersthene, approaching amblystegite, and augite, sometimes with olivine and pleonaste (hercynite), occurring as masses associated with, and as dykes intrusive in, the norites of the so-called pyroxene-granulite series of Madras; but from the resemblance of these to some forms of the norites in which they occur, I have reserved them for description on another occasion with that group, believing them to be closely related to one another.

(3) AUGITE-DIORITE GROUP.

(a.) *Holocrystalline varieties with micropegmatite.*

58. The members of this group are distinguished from those described above, by (1) the predominance of augite amongst the pyroxenic constituents;

(2) a tendency to approach an ophitic structure by an earlier development of the felspar as compared with the pyroxene;

(3) the invariable presence of quartz as a micropegmatitic intergrowth with felspar playing the rôle of groundmass.

These characters are true for a large number of dykes intruded into the gneisses, pyroxene-granulites and Dharwar Transition rocks of the Madras Presidency, as well as of some lava-flows in the Poolumpett beds of the Chey-air group Cuddapah system.¹

59. The most convenient specimen to introduce this group was collected by myself in September 1893, from a large dyke west of Isa Pallavaram, 11 miles south of Madras city (No. 9,393). It is a black, tough rock with a specific gravity of 3.10. Under the microscope it is seen to be composed of enstatite, augite, opaque iron-ores, biotite and plagioclase with micrographic patches of quartz and felspar. The plagioclase is distinctly the latest constituent to *complete* its crystallization, but it is by no means as distinctly ophitic in character as in the more basic groups already described; but it recalls the structure of some members of the preceding group in the occurrence of blade-like crystals bent around the pyroxenes (*cf.* para. 56). The presence of enstatite in considerable quantities, biotite in small quantities and the late formation of the felspar connect it with the two previous groups, whilst the predominance of augite amongst the pyroxenes and the presence of large quantities of micrographic quartz connect it with the third, and more acid, group of dykes.

60. *Enstatite* was evidently the first mineral to crystallize. It is generally colourless, but sometimes shows a faint pleochroism. It is very frequently surrounded by pale *augite*, whose junction with it can only be detected by polarized light,

¹ For comparison with trap-flows in other Transition systems of Peninsular India, see para. 79.

the cleavage-cracks being continuous, although the augite generally has a brown tint in irregular patches. Between crossed nicols the junction is seen to be very irregular and accompanied by isolated patches of augite scattered through the portions of the enstatite lying near the junction-line, producing complicated intergrowths of the two minerals. The augite generally presents darkened external borders, which are often accompanied by the formation of minute crystals of hornblende and may be a preliminary stage in the process of amphibolization. It is a very common feature in rocks of this type.

For an examination of the characters of the augite a specimen from the Seven Pagodas (No. 9,678) whose bulk analysis is given below (paragraph 71), was selected on account of its being practically free of enstatite. A chemical analysis of separated and carefully picked pyroxene gave the following results :—

Si O ₂	.	.	.	50.02
Al ₂ O ₃	.	.	.	5.61
Fe ₂ O ₃	}	.	.	15.61
Fe O.		.	.	
Mn O	.	.	.	trace
Ca O	.	.	.	14.84
Mg O	.	.	.	12.01
Alkalies	.	.	.	0.96
Loss on ignition	.	.	.	0.76
				99.81

The augite is thus remarkably similar in chemical composition to that of the monoclinic pyroxene separated by Mr. Teall from the rock of the Whin Sill, whose chemical and microscopical characters so closely resemble those of the augite-diorite dykes in the Madras Presidency. As pointed out by Mr. Teall, the resemblance in chemical composition of this mineral to the rhombic pyroxenes is, in view of the frequent association and intergrowth of augite and enstatite in these rocks, a point of considerable mineralogical interest.¹

61. The *felspar* is very commonly light brown in the central portions through the inclusion of very fine dust, but the colour becomes less pronounced as the margins of the crystal are approached, and ultimately quite colourless at the margins, where the felspar is frequently intergrown with quartz to produce the micropegmatite which occurs in every member of this group. Between crossed nicols the crystals are seen to be frequently zoned, with the more basic plagioclase forming the centres of the crystals.

62. The *micropegmatite* forms the chief point of interest in connection with these rocks. It occurs as colourless patches in the rock in which minute acicular crystals of actinolite are irregularly disseminated. The characters are so distinct that these patches can easily be detected with ordinary light. The micropegmatite in these rocks evidently represented the colourless patches already noticed in the more basic types (*supra*, paras. 31 and 34), but which only seldom contained quartz.

63. The felspar entering into the composition of the micropegmatite is sometimes crystallographically continuous with the large plagioclase crystals; but in some specimens included in this group microcline occurs.² There appears to be no

Primary origin of the micropegmatite.

¹ *Quart. Journ., Geol. Soc.*, Vol. XL (1884), p. 648.

² No. 9,795, slide, 2133; No. 9,789, slide, 2131.

reason for regarding this micropegmatite as other than original—the last phase in the consolidation of the rock. The rocks are remarkably fresh and show no signs of the secondary changes which so frequently result in the deposition of pseudomorphous quartz, whilst the felspar is, as already stated, in crystallographic continuity with the larger, unquestionably original crystals.

64. It is an interesting fact that in some cases, where secondary decomposition has just commenced, the micropegmatite patches are always the centres of decomposition (which takes the form of hydration principally), extending to various degrees around, a fact which suggests that these parts of the rock are the portions through which water circulates most freely, possibly because, being the last parts of the rock to consolidate, they are less compact; in fact, on a microscopic scale they may be miarolitic. As a glass generally possesses a lower specific gravity than the same chemical mixture when crystallized, such an occurrence might well be expected where the rock consolidates under limited pressure, and especially where such a strong framework is first produced by the previous consolidation of two intergrown minerals, pyroxene and plagioclase, which make up the principal mass of the rock. These rocks, like most of those in Peninsular India, have been remarkably free from dynamic action since their consolidation; consequently the conditions are most favourable for the preservation of such delicate structures.

65. As it is very likely that this secondary decomposition gives rise to the production of quartz, the micropegmatite may become extended by the formation of quartz in crystallographic continuity with that

Secondary extension of micropegmatite. which was original, and thus a portion of the micropegmatite is secondary in origin. Such an occurrence is well illustrated by a specimen collected by Mr. Middlemiss from a dyke $1\frac{1}{4}$ miles north of Jaulikera, Hosur taluk, Salem district.¹ In this rock the felspars have been completely decomposed in the central portions of the micropegmatite, with the formation of green chloritic products which also fringes, with decomposed biotite, the adjoining pyroxenes of the rock. In the same way the felspars are attacked, partly kaolinized, and clear quartz, presumably secondary in origin, is deposited in isolated patches, which are seen between crossed Nicols to be in crystallographic continuity with one another, and form real quartz of corrosion. In a homogeneous matrix, where free development would be possible, one would expect such secondary quartz to exhibit idiomorphic outlines, and such cases have been described and attributed to secondary enlargement of micrographic quartz.²

66. Wherever the augite comes in contact with the micropegmatite it shows signs of secondary change with the formation of green hornblende, biotite and concomitant separation of magnetite. The side of the augite away from the micropegmatite and abutting against the ordinary plagioclase generally shows no such signs of alteration. Whether this change in the augite is much later than the formation of the micropegmatite is not certain, but that contact with the latter substance is essential to its production seems certain. These changes in the augite are precisely similar to those which Professor Sollas has described as the result of the *intrusion* of granophyre into augite-diorite ("gabbro") at Barnavave, Carlingford. But in the Madras dykes it is impossible to consider these minute micro-

¹ Field number (4), 13th Feb. 1896.

² See *Quart. Journ., Geol. Soc.*, Vol. XLVII (1891) p. 177.

pegmatitic patches as other than part of the rock and derived from the same magma as the augite and plagioclase.

67. Micropegmatitic intergrowths of quartz and felspar have frequently been described in rocks of this kind. Some of these strikingly resemble the Madras dykes in their mineralogical composition; for example, the "quartz-gabbro" of Carrock Fell, which consists principally of plagioclase and augite, with enstatite often intergrown with the augite, occasional biotite, opaque iron-ores and micrographic intergrowths of quartz and felspar¹; the "gabbro" of St. David's Head which differs from the Carrock Fell gabbro in containing more biotite and less micropegmatite²; the Whin Sill, which shows variations from coarse-grained portions, in which augite becomes idiomorphic, to a hemicrystalline rock near the margins³; and the enstatite-diorite of Penmaenmawr,⁴ all intrusive in Lower Palæozoic strata.

68. Other examples have been described, but those just mentioned all strikingly resemble the Madras rocks both in mineralogical composition and in structure. The micropegmatite has generally been considered to play the rôle of groundmass and to be the last-formed constituent, but in a paper "On the relation of the Granite to the Gabbro of Barnavave, Carlingford," Professor W. J. Sollas, has described granophyric (micropegmatitic) patches in the gabbro (augite-diorite) and whilst showing that they can always be traced to minute intrusions from the associated acid rocks, suggests that the same explanation may be applied also to such cases as the Penmaenmawr rock and the gabbro of Carrock Fell.⁵

69. For want of evidence, however, as to the occurrence of "granophyres" in association with the Whin Sill. Professor Sollas admits that this explanation cannot be applied to that instance,⁶ neither can it be applied to the Madras dykes. Of the large number of dykes which show this structure in Peninsular India, not one, so far as I know, has been crossed by a later intrusion of acid rocks, and even should this happen to be the case, it still remains to be proved that such acid intrusions are not derived from the same magma, and consolidated subsequent to the basic portions as part of one continuous process. I would consequently prefer the explanation which I have already given, namely, that the micropegmatite is really original, the last phase in the consolidation of the rock, and its formation and preservation are facilitated by the perfectly quiet conditions of consolidation and subsequent freedom from dynamic disturbances. The order of consolidation of the minerals in these form a striking illustration of the normal succession according to Lagorio's law, and the formation of micropegmatite by the crystallization of the small quantity of acid mother-liquor after the separation of the basic ferro-magnesian silicates is quite in accordance with this law.

70. If, as I have suggested, the micropegmatite crystallized in the spaces

¹ A Harker, *Quart. Journ. Geol. Soc.*, Vol. L, p. 316 (1894).

² A. Harker, *Petrology for Students* (1895), p. 66.

³ J. J. H. Teall, *Quart. Journ. Geol. Soc.*, Vol. XL, p. 640 (1884), also *Brit. Petrol.*, p. 207, and plate XIII, fig. 2.

⁴ J. J. H. Teall, *Brit. Petrol.*, p. 272, plate XXXV, fig. 2.

⁵ *Trans. Roy. Irish Acad.*, Vol. XXX (1894), pp. 487—490.

⁶ During the discussion on Mr. Harker's recent paper on the granophyres of Skye, Mr. Watts pointed out that the Whin Sill at Caldron Snout passed into a rock which was practically a gabbro embedded in granophyre.

formed between the strong framework of coarsely-crystallized pyroxene and plagioclase, these microscopic miarolitic cavities were probably in imperfect communication with one another, and in this way they may represent in a sense so-called "contemporaneous" veins. It remains to be seen how far supposed intrusive veins of such rocks as graphic granite and granophyre are simple segregations into fissures, whose production have been facilitated by absence of any greater pressure than the fissured rocks are able to withstand. But this opens a wider question than the rocks under consideration afford data for discussion.¹

71. Passing on to other members of this group represented in the dykes of South India, we find that the rock of Isa Pallavaram passes gradually into more typical augite-diorites by loss of enstatite and biotite, and by a tendency for the plagioclase to crystallize at an earlier stage, being either contemporaneous with, or even later than, the augite, with a consequent tendency to the production of the ordinary ophitic type of many rocks known as diabases. Good examples of this type have been collected by Dr. Warth at Mailam (No. 9,795), Perumbakam (Nos. 9,789 and 9,790), Tirvukarai (Nos. 9,777 and 9,778), in South Arcot district; and by myself at the Seven Pagodas in Chingelput district (No. 9,678).

The last-mentioned occurrence has given specimens almost free of enstatite, the pyroxene being almost completely monoclinic. An analysis of this rock by Mr. Brühl gave the following results:—

Si O ₂	.	.	.	51.15
Ti O ₂	.	.	.	0.44
P ₂ O ₅	.	.	.	0.06
Al ₂ O ₃	.	.	.	15.92
Fe ₂ O ₃	.	.	.	9.34
Fe O	.	.	.	2.87
Mn O	.	.	.	0.09
Ca O	.	.	.	10.40
Mg O	.	.	.	6.48
K ₂ O	.	.	.	1.61
Na ₂ O	.	.	.	1.19
H ₂ O	.	.	.	0.11

99.66

The detection of microcline microscopically (paragraph 63) showing the presence of potash felspar as a constituent of the micropegmatite is confirmed by the comparatively large proportion of potash shown by this analysis. The ratios of silica to sesquioxides and protoxides differ from those of the Whin Sill no more than might be accounted for by the difference in preservation of the two rocks. The Whin Sill has undergone a certain amount of hydrous decomposition, whilst the dyke of augite-diorite at the Seven Pagodas is most remarkably fresh. Both rocks show a striking approach to the hypothetical basic magma of Durocher, which he supposed to contain 51 per cent. of Si O₂, and possessed a density of 2.96.

¹ Besides the localities already quoted some very fine examples of augite-diorites with micrographic quartz were collected by Mr. Lake during the season 1887-88 in the Bellary district and Raichur Doab, some of them occurring as dykes in the Dharwar:— Nos. 8,537, 550, 552, 558, 569, 592, 612 and 655.

(b.) Hemicrystalline varieties of the Augite-diorites.

72. As in the two preceding groups, the augite-diorites have their fine-grained and possibly hemicrystalline representatives in narrow dykes and on the selvages of the larger masses. Two of the most striking examples representing each of these conditions have been collected by Dr. Warth. The first was found as a dyke 20 feet wide at Nemeli (No. 9,784), and the second forms the selva of the large mass of Perumbakam hill (No. 9,788), both in South Arcot district.

73. In the former case (Nemeli) the pyroxene individuals are frequently found to be rhombic in the centre, exhibiting crystallographic parallelism to the augite growing around. These enstatite cores often show a pair of horns at either end giving the core very much the shape of the crystallites which Mr. Rutley has figured as "crenulites."¹ The augite is greatly in excess of the enstatite, and although it probably commenced its crystallization before the felspar, these two constituents are sufficiently intergrown to show that they mostly separated simultaneously, leaving a series of spaces which are filled in with skeleton crystals of magnetite and a micrographic intergrowth of probably felspar and quartz on an exceedingly minute scale, in some places what Harker would call *cryptographic*.² It would be interesting to follow this rock out to its selvages; but no further specimens were collected.

74. The rock which represents the selvages of the large mass at Perumbakam consists of phenocrysts of augite and olivine in a very fine-grained matrix of probably the same minerals, magnetite and small patches of biotite, forming a closely felted mass in which it is impossible to decide as to the presence of vitreous material. From the specimen alone the rock might very well be described as an augite-andesite.

75. The *phenocrysts* are often gathered into glomero-porphyrific groups showing, by their intergrowths, the approximately simultaneous crystallization of the augite and felspar. These minerals are of the usual type represented in the more perfectly holocrystalline types, and the felspars in the same way are crowded with minute inclusions, giving the crystals a light brown or grey colour. Although with the low powers the pyroxene appears to be almost wholly augite, examination with the high powers shows on a minute scale the micropertthite-like structure, which may possibly be due to an intergrowth with rhombic pyroxene.³

(c.) Volcanic representatives of the Augite-diorites.

76. Although the contemporaneous lava-flows of the Cuddapahs are represented by a very limited number of specimens in the Geological Museum, those which have been collected strikingly resemble the dyke-rocks already described in mineralogical composition and in structure. Probably the most typical representative of the augite-diorite group is

Bétumcherú lava-flow.

¹ *Min. Mag.*, Vol. IX, plate, figs. 18, 19 and 20.

² *Petrology* (1895), p. 92.

³ A similar rock was collected in 1886 by Mr. R. Bruce Foote in the Bellary district and recorded by myself from the hand-specimen as an augite-andesite [No. 9,454; *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 40 (1894)].

the lava-flow near Bétumcherú, in the Kurnool district, which is a member of the Poolumpett beds of the Chey-air stage, Cuddapah system.

77. Mr. P. Lake¹ has shown that this rock is composed principally of augite and plagioclase with a little magnetite, and has a specific gravity of 3.0. Further examination shows the presence, according to my determination, of considerable quantities of quartz which often forms micrographic intergrowths with the felspar, and a very small quantity of enstatite with occasional flakes of biotite. The relations of the augite to the felspar are precisely those which characterise the augite-diorite group amongst the dyke-rocks, the rock being sub-ophitic. Secondary decomposition has resulted in the partial kaolinization of the plagioclase and in the formation of a microcrystalline chloritic product from the augite.²

(d.) *Occurrence of augite-diorites with micrographic quartz in other Transition systems.*

78. It is interesting to find very similar augite-diorites with micrographic quartz associated with many of the other Transition systems of Peninsular India which resemble a portion of the Cuddapah system in other lithological characters. Many of these are dykes and consequently cannot be relied upon as evidence for the purposes of stratigraphical correlation; and although the small number of specimens collected from undoubted contemporaneous trap-flows agree very remarkably with the augite-diorites of the Cuddapahs in petrological characters, far more evidence of a precise character is necessary before the characters of the volcanic rocks can be added to the other lithological evidence which forms the only data available for the stratigraphical correlation of these unfossiliferous systems of the Peninsula.

79. Amongst the contemporaneous traps of the Transitions containing micropegmatite which are represented in the Calcutta collection are principally from the Bijawars (Nos. 5,³ and 5,10, which contain olivine and are beautifully ophitic; Nos. 32,126 and 55,34, which have been greatly altered, the latter showing the "herring-bone" structure due to lamellation parallel to the basal plane so frequently noticed by Teall, Harker and others) and the Gwaliors (No. 12.49). The last-named from the Barai trap-flow of the Gwalior Transition series,³ contains porphyritic crystals of plagioclase, now considerably decomposed.⁴

IV.—SUMMARY OF RESULTS.

80. The dykes intrusive in the gneisses and Dharwar Transition rocks of Southern India, as the well as the Cuddapah lava-flows, which are supposed to be their volcanic representatives, vary from *olivine-augite-norites* (enstatite-olivine-

¹ *Rec. Geol. Surv. Ind.*, Vol. XXIII, p. 261 (1890).

² Another specimen obtained by Dr. King, 3 miles W. S. W. of Bétumcherú (No. 97,92) is an amygdaloidal, fine-grained variety of apparently the same rock; but is too far decomposed to permit a correct determination of its original characters.

³ See Hacket, *Rec. Geol. Surv. Ind.*, Vol. III, p. 38 (1870).

⁴ I have also found micrographic quartz in very similar augite-diorites intrusive in the unfossiliferous palæozoic slates, dolomites and quartzites of Naini Tal and in Garhwal (Nos. 9,737, 850, 854, 866).

gabbros) sometimes approaching saxonite (harzburgite) in composition, to *augite-diorites* (gabbros) with *micrographic quartz*.

81. *Hemicrystalline representatives* of these rocks occur in narrow veins and as selvages to larger masses. Two of these are exceptional types related to the magma-basalts and augitites. In one case olivine is the only phenocryst in a black cryptocrystalline matrix. In the other the only phenocryst is enstatite which lies in a microlithic matrix of augite and probably felspar with residual glass. The enstatites are enclosed in a thin shell of augite, which is frequently in crystallographic continuity with isolated fragments of augite within the enstatite.

82. In the most basic members of the series, olivine is the first constituent to crystallize, and is followed in order by enstatite, biotite and plagioclase. The plagioclase grows around its associates in crystals sufficiently large to give a distinct "lustre-mottling" to the hand specimens of the coarse-grained varieties. In the less basic types, which are wanting in olivine, the enstatite, augite, biotite and felspar are crystallized in the same order. In the least basic forms, enstatite is either absent, or present in subordinate quantities, forming nuclei for the augites, which exhibit in these types a tendency to crystallize at a later stage, being developed mostly simultaneously with the felspar even to produce in some cases a subophitic structure.

83. The *micropegmatite* is evidently the latest constituent to consolidate. It is composed of quartz and either plagioclase or a potash-felspar, which is sometimes in the form of microcline. When the quartz is intergrown with plagioclase, the latter is generally in crystallographic continuity with large adjoining crystals. The plagioclase-felspars are brown or grey in their central portions, on account of innumerable inclusions. As the periphery of the crystal is approached the colour becomes less pronounced, and the felspar, as shown by its change in extinction-angle, less basic, until at the margins, where it is intergrown with quartz to form the micropegmatite, it and the quartz become quite "water-clear," but then they invariably contain numerous acicular inclusions of a mineral resembling actinolite. These "water-clear" micropegmatite patches fill in the angles between the large crystals of felspar and augite, and though evidently younger than either of these minerals, must be regarded as crystallized in direct succession to them as the last-formed constituent during the primary consolidation of the rock.

84. In the majority of the dykes the only signs of alteration are in the formation of green hornblende and biotite with concomitant separation of magnetite where the augite comes in contact with the micropegmatite. These changes are never shown except on the sides of the augite nearest the micropegmatite. They are precisely similar in character to the alterations induced in the augites of the Carlingford gabbro (augite-diorite) by intrusions of "granophyre" (Sollas, *Trans. Roy. Irish Acad.*, Vol. XXX (1894), p. 493). But it would be impossible to regard such excessively minute patches of micropegmatite, whose felspars are in crystallographic continuity with the ordinary plagioclase-constituents of the rock, as intrusive, and such a conclusion, in the complete absence of connection with larger acid intrusions, would be quite an unjustifiable alternative to the explanation offered above (para. 83). When the rocks show signs of hydrous decomposition, the micropegmatitic patches are always found to be the centres of action. One result of this decomposition is a secondary extension of the micropegmatite by deposition of genuine "quartz of corrosion" in the surrounding felspars.

85. As the consolidation of the rock resulted first in the formation of a strong framework of coarse augite and felspar crystals, the spaces left, and now occupied by the micropegmatite, must have been in partial communication with one another. As a glass occupies a greater space than the same substance when crystallized, the micropegmatitic portions must be less compact than the rest of the rock, and being protected by the strong framework of augite and plagioclase from the pressure brought to bear on the rock as a whole, might give rise even to the production of microscopic miarolitic cavities. As these loose-textured portions are in communication with one another, they become the channels of water-circulation and consequently appear in sections as the centres of hydrous decomposition.

86. Although, as already stated, the micropegmatite in the fresh, undecomposed rocks is regarded as primary in origin and subsequent in formation to the augite and plagioclase, the considerations stated in the previous paragraph suggest that its formation is not a simple continuation of the normal crystalline consolidation of a molten magma. Any water which may have been in the original molten material would be reserved in the "mother-liquor" after the separation of the augite and plagioclase, so that the changes which subsequently occurred in the communicating inter-crystal spaces would be of an aqueo-igneous nature. This accounts perhaps for the peculiar appearance of the "water-clear" patches of micropegmatite with their acicular actinolitic inclusions, recalling at once the similar quartz which is generally regarded as secondary in decomposed rocks, and explains also the alteration of the augite where it comes in contact with the micropegmatite.

87. In describing the "granophyric gabbro" of Barnavave, Carlingford, Professor Sollas (*Op. cit.*, pp. 487—490) traced micropegmatitic patches in an augite-diorite to thin veins of "granophyre," which he regarded as intrusions of material in a state of great fluidity, and suggests that this explanation may apply also to the similar well-known cases of Carrock Fell and Penmaenmawr which are found to be in association with large masses of "granophyre." For want of evidence, however, as to the occurrence of "granophyres" in association with the Whin Sill, Professor Sollas admits that this explanation cannot be applied to the similar occurrence of micropegmatite in that rock. Neither can it be applied to the Madras dykes, which are not, so far as I know, crossed by any later intrusion of acid material. The explanation which I have offered in connection with the Madras rocks appears to account for the primary formation of micropegmatite in these rocks, as well as its secondary extension.

88. Accepting Professor Sollas' precedent for extending an explanation beyond the limits of the material under description, I would suggest the application of the explanation now offered for the Madras dykes to such cases as the Whin Sill, Carrock Fell gabbro and the Penmaenmawr enstatite-diorite; and further to suggest that even distinct veins of granophyre instead of being considered normal igneous intrusions, can best be explained as "contemporaneous veins" formed as the final stage in the consolidation of the magma from which the augite-diorite was obtained during the earlier stages of its consolidation. When the consolidation takes place under limited pressure, as was probably the case with these Madras dykes, the framework of augite and plagioclase will be sufficiently strong to prevent collapse, and the micropegmatite can thus

consolidate in the intercrystal cavities. But where the pressure is in excess of that which the framework of augite and plagioclase is able to withstand, as is more likely to be the case in large masses, the mother-liquor will be squeezed out and will consolidate as a separate mass of granophyre. Some such explanation as this I would offer to account for the frequent association of masses of augite-diorite (gabbro) with granophyre; or in other words, to account for the separation of these genetically related rocks when the magma is sufficient to form large bosses, and for their intimate microscopic association where the magma consolidates in narrow dykes.

89. Like the pyroxene-granulite series in which these basic rocks occur so frequently as dykes, they are remarkably fresh. Even the olivines show practically no signs of decomposition in the dyke-rocks and have suffered only slightly in the lava-flows, whilst signs of dynamic metamorphism are absolutely wanting. These facts are in complete agreement with the known stratigraphical history of Peninsular India which has been so remarkably free from crust disturbances since Palæozoic times.

90. As the effects of subaërial weathering must be very superficial compared to the results of the action of water charged with carbonic acid under the high pressures at the bottom of an ocean, the fresh condition of the olivine and other minerals susceptible to hydrous decomposition in these rocks is in agreement with the absence of any evidence as to the deep submergence of the parts of South India where these rocks are exposed.

91. The absence of all signs of amphibolization in the augites, which are so susceptible to the effects of dynamic metamorphism, is in agreement with the undisturbed state of all rocks younger than the Cuddapahs in Peninsular India, whilst the same feature serves generally to distinguish the basic igneous rocks of post-Cuddapah age from the epidiorites and other highly altered eruptives associated as contemporaneous lava-flows with the older Dharwar Transitions.

92. Although such petrological features can never be relied on alone for purposes of stratigraphical correlation, it is worthy of remark that augite-diorites with micrographic quartz, and equally well-preserved, occur in Transition systems like the Bijawars and Gwaliors in other parts of Peninsular India, which have generally been considered older than the Cuddapahs; but which agree, however, with the lower stages of this system in many other lithological characters.

V.—EXPLANATION OF PLATES.

PLATE I.

Fig. 1.—Olivine-norite, S. of Kaithaha, near Saria on the Sone river, Ramnagar Tahsil, Rewa State. No. 10,588; slide 2125. Magnified by 20 diameters. Olivine in rounded crystals with reaction-rims of a colourless granular enstatite forming the inner zone and fibrous actinolite forming the outer zone. The colourless portion is plagioclase in which two crystals of enstatite are shown. Where the small enstatite crystal, near the upper margin of the slide, approaches olivine the only sign of a reaction-rim is a thin band of the colourless granular mineral separating the enstatite crystal from

the olivine. Such thin bands of the colourless mineral are often found in crystallographic continuity with the neighbouring primary crystal of enstatite.

Fig. 2.—Olivine-enstatite-basalt.—Dyke in “pyroxene-granulites,” Coonoor, Nilgiri hills, Madras Presidency. No. 8,759; slide No. 1599. Magnified by 20 diameters. The phenocrysts in this rock are olivine, enstatite and plagioclase. There are numerous glomeroporphyrific aggregates formed of one crystal of olivine in the centre with numerous enstatite-crystals around. Such a group is shown in the centre of the field. The matrix is pilotaxitic, possibly hyalopilitic, containing augite, biotite, enstatite, felspar and magnetite. Towards the central portions of this dyke the crystals of the groundmass are more clearly-defined, and the pleochroism of the rhombic pyroxene often well exhibited. (See paras. 36—38.)

Fig. 3.—Magma-basalt without augite.—Thin vein in “pyroxene-granulite,” near Poorsy, north-north-west of Wandiwash, Madras Presidency. No. 1,842; slide No. 2027. Magnified by 80 diameters. The rock has a black, almost opaque, cryptocrystalline or glassy matrix in which olivine phenocrysts only occur. The crystals are well shaped, zoned and often corroded by the magma, as shown by this specimen. The cracks running across the matrix are filled in with colourless decomposition-products.

Fig. 4.—Olivine-norite-variolite.—Selvage of vein 2 feet wide in “pyroxene-granulite,” Coonoor, Nilgiri hills, Madras Presidency. No. 8,757; slide No. 2198. Magnified by 20 diameters. The varioles are brown in colour and sprinkled with magnetite-dust. Glomeroporphyrific aggregates of olivine and enstatite precisely resembling those shown in fig. 2, as well as isolated crystals of enstatite, are scattered through the cryptocrystalline matrix.

Fig. 5.—“Norite-felsite,”—Dyke 20 feet wide in “pyroxene-granulite,” Eriyūr, South Arcot district, Madras Presidency. No. 9,782; slide No. 2197. Magnified by 20 diameters. Porphyrific crystals of colourless enstatite in a matrix of augite and long microlites of felspar with black interstitial matter, which may be vitreous. The way in which the long microlites of felspar are wrapped around the pyroxenes forms a perfect imitation on a very small scale of the blades of plagioclase in the coarse-grained rock from Salem described in para. 56. The large phenocrysts of enstatite are generally encased in a thin shell of augite, which is seen between crossed Nicols to be in crystallographic continuity around, and often also with apparently isolated fragments of augite within, the enstatite phenocrysts. This rock bears to the augite-norites precisely the same relation as a felsite does to a granite. It may therefore be called a “norite-felsite,” or any convenient name

which indicates that its composition is that of a norite and its structure felsitic.

Fig. 6.—Augite-diorite with micropegmatite.—Dyke in "pyroxene-granulite," Mailam, South Arcot district, Madras Presidency. No. 9,795; slide No. 2133. Magnified by 12 diameters. Crossed Nicols. The rock is composed of augite, plagioclase and a micropegmatitic intergrowth of quartz and felspar playing the rôle of groundmass and regarded as primary in origin.

PLATE II.

Fig. 1.—Basal section of olivine crystal, showing the traces of brachypinacoidal cleavage planes crossing the cut edges of the dendritic inclusions at right angles. The quartz wedge shows the latter to lie in the direction of the axis of maximum optical elasticity α , whilst the cleavage cracks are parallel to the axis of minimum optical elasticity ϵ (See para 13). From *Olivine-augite-norite*, near Saria Rewa. Rock No. 10,588; slide No. 2125. Magnified by 180 diameters.

Fig. 2.—Intergrowth of pyroxene-crystals, showing the peculiar microperthite-like structure in one of the individuals (P). The positions of extinction in the individuals P, P_I, P_{II}, and P_{III} respectively are shown by the arrows. From the same *Olivine-augite-norite*; slide No. 1895. Magnified by $\frac{1}{2}$ diameters. (See para. 18.)

Fig. 3.—Reaction-rim between olivine and plagioclase. O=Olivine, P=Plagioclase, E=Enstatite with its secondary enlargements, e , which are in crystallographic continuity with the original crystal E, and in one place form part of the reaction-rim with the green actinolite, a . It will be noticed that the actinolite, a , appears only between the secondary enstatite, e , and the plagioclase, not between the latter mineral and the primary enstatite, E. E. shows feebly the pleochroism of hypersthene, whilst e is perfectly colourless. Slide No. 2125. Magnified by $\frac{1}{2}$ diameters. (See para. 14.)

Fig. 4.—Augite-andesite, forming the marginal portion of a large mass of augite-diorite with micropegmatite at Perumbakam, South Arcot district, Madras Presidency. It consists of a hyalopilitic groundmass of augite, plagioclase, biotite, magnetite and glass with phenocrysts of augite (A) and plagioclase felspar (F) showing in the glomero-porphyritic groups approximately simultaneous crystallization of the two minerals. Rock No. 9,788; slide No. 2130. Magnified by $\frac{1}{2}$ diameters. (See para. 75.)





Fig 1

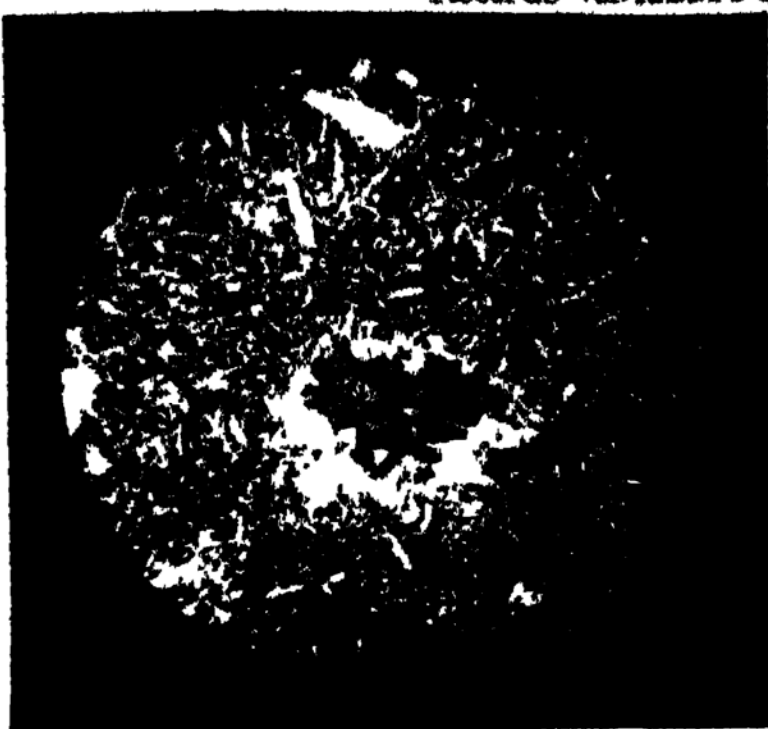


Fig 2

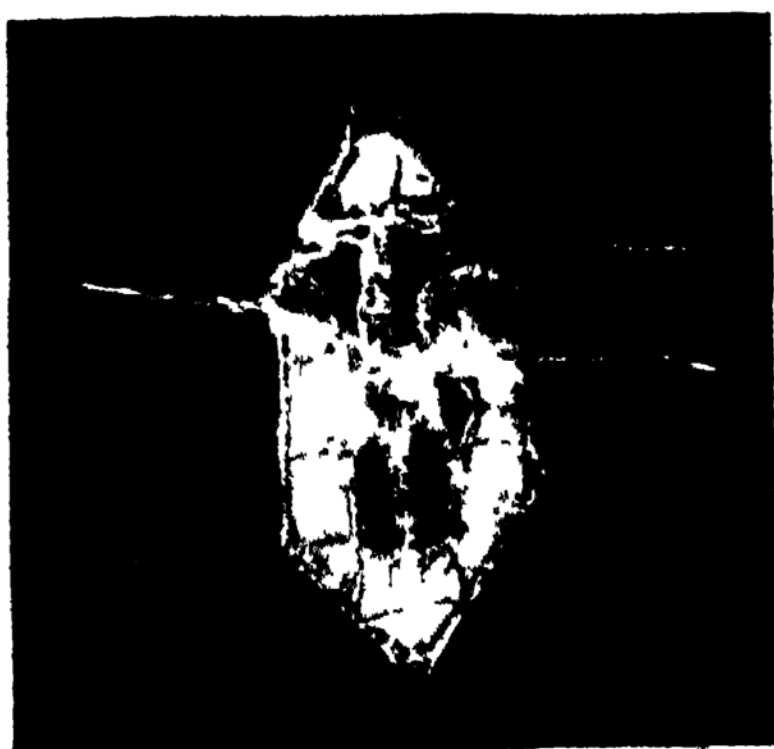


Fig 3

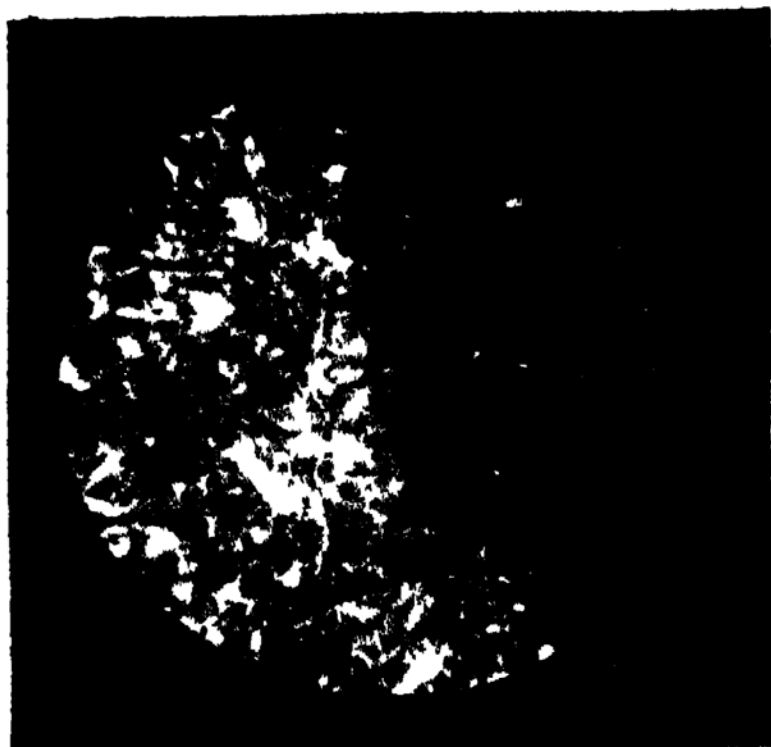


Fig 4



Fig 5



Fig 6.

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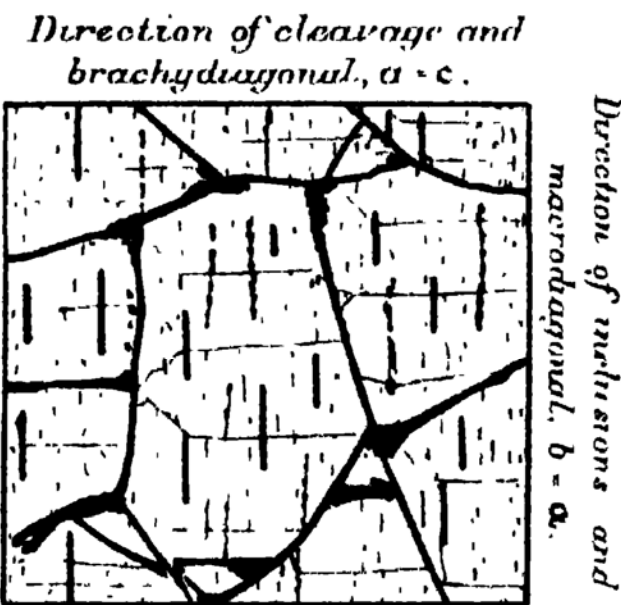


Fig 1



Fig 2



Fig 3.



Fig 4.

BASIC DYKES OF PENINSULAR INDIA.

*The reference of the genus Vertebraria by M. R. ZEILLER; translated by E. VREDENBURG, A. R. C. S., Assistant Superintendent, Geological Survey of India.*¹

Few fossil genera have so much perplexed the minds of most eminent palæobotanists for the last 50 years as the genus *Vertebraria*, without any definite conclusion having been arrived at respecting its true affinities. This genus was established by Royle in 1839 to include flattened axes of varying width, usually with a more or less distinct median groove, giving off at right angles transverse furrows more or less irregularly spaced, sometimes alternate, sometimes opposite, and dividing either side of the impression into a series of successive joints. Moreover, the widest specimens usually exhibit upon each side other longitudinal grooves parallel with the central one, only not so distinct. These grooves, longitudinal as well as transverse, may be replaced by projecting ridges, according to the mode of preservation of the fossil. The axes are either simple or provided with branches, alternately disposed on either side, but irregularly spaced.

A few specimens lying at right angles to the planes of bedding, show upon their cross section a series of wedge-shaped segments radiating from a common centre and more or less closely packed; this led some authors to arrive at a conclusion, which was subsequently recognised as unfounded, that they were *Sphenophyll-oideæ* with very numerous leaf-whorls, close set along the stem. Bunbury regarded the specimens he studied as roots. O. Feistmantel who has had the opportunity of examining a large number of specimens obtained from India and Australia, concluded, but without committing himself any further, that *Vertebraria* is the root or rhizome of some other plant, and probably of an Equisetaceous plant such as *Schizoneura* or *Phyllotheca*; but this view seems difficult to accept as the transverse folds of *Vertebraria* often intersect only half the structure, and the existence of real articulations like those of the *Equisetaceæ* appeared far from evident.

Up till now, *Vertebraria* had been met with only in India in the lower Gondwana series, and in Australia in the Newcastle beds. I have recently been able to detect its occurrence in another region, the permo-triassic deposits of the Transvaal belonging to the Beaufort stage; it is fairly abundant amongst the specimens collected by M. de Launay, mining Engineer, in the neighbourhood of Johannesburg. It is associated, as in Australia and India, with numerous impressions of *Glossopteris*, and as very few other vegetable remains are met with, I was led to consider whether this association of *Glossopteris* and *Vertebraria* did not indicate some mutual relationship.

By splitting up these Transvaal specimens and carefully developing the impressions which they contained, I was soon able to ascertain the presence, upon several specimens of *Vertebraria*, of more or less abundantly ramified roots starting from some of the transverse grooves, from which I was able to infer that they are undoubtedly rhizomes. Further, a study of the structures exhibited by the impressions has enabled me to conclude that these rhizomes consisted of a central axis provided with a variable number of longitudinal wings anastomosing two by

¹ *Comptes Rendus*, cxxii, 744. I am indebted to Surgeon-Major D. Prain, Curator of the Herbarium, Royal Botanical Gardens, Sibpur, for kindly revising the translation.—R. D. O.

two from place to place; the characteristic transverse grooves observed upon the surface corresponding to these anastomoses.¹

Now such a disposition is actually met with in certain ferns, particularly in *Struthiopteris germanica* whose rhizome is provided with a variable number of columns (*stèles*) each situated towards the extremity of a projecting wing, and successively uniting two by two to give rise to the leaf-bundles. If the leaves of such a rhizome were fewer and not so regularly spaced it would produce an impression resembling that of *Vertebraria*. The irregularities shown in the interspacing of the transverse furrows could not, however, invalidate the reference of this fossil genus to the ferns, some of which, particularly *Oleandra*, exhibit at the present day, still greater irregularities with regard to the distribution of their leaves, which may be more or less apart, or else closely packed in pseudo-verticils.

It appeared probable to me, therefore, that *Vertebraria* belonged to *Glossopteris*, but this was only a conjecture requiring further verification if possible. By means of a minute examination of the impressions collected by M. de Launay, I have been fortunate enough to verify this point. First I was able to follow up to its base a *Glossopteris* leaf fixed to a *Vertebraria*, and to observe that its midrib bent round so as to fit exactly into a transverse furrow of this rhizome where it terminated; their mutual relation was, however, not altogether beyond doubt, and therefore, although such a coincidence would seem most unlikely, it might still have been objected that this was merely an accidental juxtaposition. At last, on a specimen exhibiting a more distinct transverse folding, which assumed the appearance of a leaf scar, I was able to discover a group of bundles starting from this anastomosis of longitudinal ridges and, following it outwards, to discern its continuation into the midrib of a *Glossopteris* leaf, imperfectly preserved, but perfectly recognisable.

Vertebraria is therefore nothing but the rhizome of *Glossopteris*, and this observation at once solves the problem of its interpretation and adds greatly to our knowledge of this genus of Ferns which has played so important a part in the flora of one of the two great botanical provinces of the close of the palæozoic era. Somewhat similar in habit to *Oleandra*, that is with leaves now wide apart, now clustered in tufts, *Glossopteris* had winged rhizomes very analogous to those of *Struthiopteris germanica*. As in the last mentioned plant these rhizomes in all probability gave off stolons provided first with leaf-scales and producing only after a time normally developed leaves. I have indeed noticed amongst the Johannesburg impressions, numerous scales, triangular or oval in outline, the limb of which appears to have been rather thick and coriaceous, whose anastomosing venation is sometimes remarkably similar to that of *Glossopteris*; one of them, more completely developed, comes so near, both in shape and dimension, to certain leaves of *Glossopteris browniana*, that its reference to this species seems to leave no room for any doubt. Contrary to what takes place in *Struthiopteris germanica*, where the two kinds of leaves, underground scales and aerial fronds, remain absolutely distinct, it would appear that in *Glossopteris*, whose stolons were perhaps epigæous, there was a gradual passage from scales to normal leaves.

¹ In the original: "ces rhizomes étaient formées d'un axe central muni d'un nombre variable d'ailes longitudinales s'anastomosant deux à deux de distance en distance, les cannelures transversales caractéristiques q'on observe à leur surface correspondent précisément à ces anastomoses." As will be seen from the succeeding paper the structure of the Indian specimens is not in accord with this description.

On a Plant of Glossopteris with part of the rhizome attached, and on the structure of Vertebraria, by R. D. OLDHAM, Officiating Director, Geological Survey of India (with Plates III to V).

The interest of the foregoing paper, as not only extending the range of the characteristically Indian genus *Vertebraria*, but also settling its true botanical nature, so long in doubt, has seemed sufficient to justify the publication of a translation in the Records of the Geological Survey. Besides its purely botanical and geological importance it is of interest in adding yet another to the long list of instances of independent and simultaneous discovery. During the last working season I was fortunate enough to find, in the lower Gondwanas of south east Rewah, a bed crowded with the remains of *Glossopteris*, *Macrotaeniopteris*, *Schizoneura*, etc., and among them a specimen, figured on Pl. III, of a clump of *Glossopteris communis* fronds, evidently springing from a fragment of the rhizome. The specimen was sufficiently striking to attract the notice of the labourers I had employed to dig out the bed, but unfortunately the most careful search failed in discovering either the reverse impression or the continuation of the rhizome; the one specimen figured is consequently all the material available. The state of preservation of the specimen is not all that might be desired, but it is sufficient to enable the generic and specific position of the plant to be determined without doubt; the peculiar manner of association of the group of fronds is incompatible with any supposition other than that they originally formed part of the same plant, and it would be unreasonable to suppose that the position of the fragment of rhizome at their joint bases is merely accidental; we may take it therefore that we have preserved a whole plant of *Glossopteris* with a portion of its root-stock. This is of itself interesting as showing the habit of growth of the plant, but besides this the small rhizome shows indistinctly, it is true, but recognisably, the median ridge and transverse partitions of *Vertebraria*. Taken in conjunction with Mr. Zeiller's observations this specimen may, therefore, be regarded as establishing the true nature of *Vertebraria* as the rhizome of a fern and not, as is more often supposed, of an equisetaceous plant.¹

The discovery of the botanical position of the *Vertebraria* naturally revives the interest in its structure, and as this is but imperfectly treated in any of the descriptions I have come across, I have made a re-examination of the material in the Museum of the Geological Survey and offer the following description of the facts disclosed without any expression of opinion as to their botanical application.

In its most common and typical form *Vertebraria* is preserved as an impression on the surface of bedding of shale or sandstone. This long, and generally narrow,

¹ It may be of interest to note that this is not the first specimen of a clump of *Glossopteris* fronds which has been found in India. This specimen figured by Dr. Feistmantel, under the name *Sagenopteris* (?) *longifolia* (Pal. Indica, ser. xii, III, pl. XLA, fig. 1) is in a very poor state of preservation, but can be recognised as a group of fronds of *Glossopteris* type, resembling *G. communis*. One side only of the stalk is preserved, but that shows distinct signs of a transverse articulation. The specimen is evidently of a similar nature to that found in S. Rewah, and resembles this so much that, with all deference to Dr. Feistmantel's authority, I feel constrained to regard it as properly belonging to the genus *Glossopteris*, and not to *Sagenopteris*, to which he doubtfully assigned it.

impression is typically divided down the centre by a ridge or a furrow, and on either side divided by transverse prominences and grooves, generally arranged alternately in either half, and in the most perfectly preserved there is usually an elevation and furrow close together and then an interval between them and the next pair. Occasionally the divisions on either side of the median axis are opposite each other, but as a rule they are not so, and the occasional continuation of one of the transverse divisions on the other side of the central axis is evidently accidental. In another shape, described as *V. radiata* by Royle,¹ it appears on the face of the bedding plane as a series of triangular impressions arranged round a central axis; in section across the bedding plane, it is seen to be composed of number of close set layers, and it was this form which led McCoy to class *Vertebraria* with the *Marsiliacæ*² and Unger³ and de Zigno⁴ to describe it as a *Sphenophyllum*, all three authors looking on the fossil as the remains of a central stem with close set whorls of leaves.

This description is irreconcilable with the fact that the two forms are clearly a different mode of preservation of one and the same thing, and moreover a close examination of specimens of *V. radiata* show the occasional preservation of an outer shell of coaly matter and of a similar substance occupying the intervals between what would be the edges of the leaves and connecting one with the other in a vertical direction. It is clear in fact that *V. radiata* was a stem with a central axis, connected with the outer shell by radiating longitudinal septa, which again were connected by close set transverse septa in each segment. The ordinary form of *V. indica* would be the impression of a similar stem in which the septa were at longer intervals apart, and which in consequence of the smaller resistance to crushing resulting from this, has only been preserved as a flattened impression.

It would be quite possible to explain the peculiar markings in the manner in which M. Zeiller has done, and this hypothesis would fit in with the occasional occurrence of two or even three longitudinal divisions and of three or four bands of transverse ridges and depressions. Fortunately, however, there are in our collection some specimens of *Vertebraria* from the Aurunga field, preserved in a different manner, which throw great light on the structure of *Vertebraria*. In these the vegetable matter has been converted into a dark brown ferruginous substance, round which the matrix is indurated with a ferruginous cement. The rest of the matrix, whether sandstone or shale, is soft and in many cases easily cleared away from the fossil. The *Vertebraria* shows up either as a transverse section on the face of the rock, or when the axis runs along the exposed surface, as projections, differing in appearance from the more usual form, but easily recognisable as the same thing preserved in a somewhat different manner. The first of these to be noticed is that represented in pl. IV, figs. 2-5, which I have succeeded in developing from a piece of sandstone, on which only the ends and part of one side of the fragment were originally visible.

Here the end view fig. 2, shows a central axis and a series of radiating wings,

¹ Illustrations of the Botany and other Branches of the Natural History of the Himalaya Mountains, Plate II, fig. 5, 6, 7.

² *Ann. Mag. Nat. Hist.* XX, 145 (1847).

³ *Genera et species Plantarum Fossilium*, 1850, p. 71.

⁴ *Flora Fossilis Formations oolithicæ*, 1856, p. 52, where Ettingshausen is quoted as taking the same view.

which are not connected at their outer extremities. It must not, however, be concluded from this, that the stem was of a stellate section, for in specimens of the ordinary sort the remains of an outer coating of carbonaceous matter can sometimes be found, though it was evidently thin and perishable. Even in the specimen under consideration there are traces of an expansion at the end of the rays which must represent a part of the original rind; and in other specimens of the same nature, and from the same locality, this is partly preserved as shown in pl. V, fig. 4. It will be noticed that the longitudinal septa do not all radiate from the central axis, but that in one case the septum bifurcates and gives rise to two septa; moreover, a comparison of figs. 2 and 3 shows that the point of bifurcation of the septum is further removed from the axis at one end of the specimen than at the other.

The transverse septa are well seen on the sides of the specimen; in fig. 3 the broad triangular patch is one of the septa exposed on the broken end of the specimen and on the others, the manner in which each longitudinal section is independently divided by transverse septa is very clearly shown.

The two next specimens to be described have both been figured before,¹ but are reproduced here, one for convenience, the other because the specimen has been developed so as to show more than was originally to be seen. In pl. V, fig. 3, we have three longitudinal ridges, united at irregular interval by transverse bars, which there is no difficulty in recognising as a variant of the typical form in which *Vertebraria* is preserved. In fig. 2 we have four ridges and three sets of transverse bars. In the specimen, more clearly than in the figure, it is possible to make out that the longitudinal and transverse ridges represent the ends of corresponding septa, while in the section made by obliquely truncating the end of the impression, the septa, corresponding at their terminations to one of the longitudinal ridges, can be seen radiating from a central axis.

In the next specimen to be described the mode of preservation is somewhat different; instead of being converted into iron oxide the vegetable matter has disappeared leaving a cavity in its place. The specimen (pl. V, fig. 1) shows a longitudinal section, the rock having broken through the cavity left by two opposite radial septa, and from the surface of the mould a series of clefts penetrate vertically downwards and represent the transverse septa. Another longitudinal septum is represented by a cleft penetrating obliquely into the rock, and the transverse clefts running down from it can be seen in close proximity to, but not as a rule coincident with, those above.

From these specimens to the more usual form of preservation is a short step, and we can recognise the latter as the impression of the flattened stem, the longitudinal divisions representing the impression either of the central axis or the ends of radial septa, and the transverse ones the impression of the transverse septa, which sometimes occur opposite each other, but more commonly are not coincident. Sometimes, instead of being merely the impression of a crushed stem, the hollow spaces between the septa have become filled with sand, and the *Vertebraria* appears as a series of separate joints, between which thin partings of coaly matter are seen.

In the rarer forms of preservation described above there is seldom any trace of an outer sheath connecting the ends of the radial septa, but in the more usual

¹ Pal. Indica, series xii, IV, Pl. IVa, fig. 5, 9.

mode of preservation there is not uncommonly an outer film of coaly matter, and in two specimens figured by Dr. Feistmantel¹—the outer sheath is conspicuously preserved, and can be seen to have been smooth, with a longitudinal striation; moreover, the flattening undergone by the stem in the ordinary mode of preservation shows that the matrix could not obtain a ready access to the intervals between the septa. It would seem, however, that the outer rind must have been much less substantial and more perishable than the central core or the septa.

Summing up the evidence we find that *Vertebraria* consisted of a central axis, more or less well marked, joined to an outer rind by a series of radial septa, which are usually eight in number in those specimens preserved so as to show a transverse section, and having the spaces between the radial septa divided into chambers by transverse partitions. The transverse partitions on either side of each radial septum are in no case coincident with each other, and there is an appearance of their being arranged spirally round the central axis, but the material available is insufficient for the establishment of this point. From the readiness with which the interspaces between the septa become filled by the matrix and the completeness of their obliteration where this is not the case, it is probable that they were air chambers and not filled with any form of cellular tissue, however soft and perishable.²

Branching of these stems takes place in two distinct ways. Either as in pl. IV, fig. 1, the central axis itself breaks up into two or more branches, or branches are given off from the side of the stem. There are numerous specimens showing this latter and more common form of ramification, several of which have been figured by Dr. Feistmantel. It is not always possible to make out clearly the exact point at which the stem and branch join, but in all those which I have examined the junction seems to take place exactly on one of the transverse septa and, as far as can be made out, at its junction with a longitudinal septum. In some cases the junction seems not to coincide with any transverse septum, but in these cases the appearance may be deceptive and has, besides, only been observed in thin branches or rootlets, which do not exhibit the typical *Vertebraria* structure and may be functionally different. On the whole, however, the statement above seems to represent the facts, but certainty will only be attainable after the careful development of specimens well preserved in the round.

P. S.—The foregoing description had been written and set up in type for publication in part 4 of the Vol. XXIX of these Records, but had to stand over to the present number owing to a delay in the preparation of the plates. Meanwhile we have received, through the courtesy of M. Zeiller, a copy of a more detailed description³ published by the Geological Society of France with full illustrations of the specimens studied by him. The description and diagrams leave no doubt of his interpretation of the structure of *Vertebraria*, and it is evident that the in-

¹ Pal. Indica, series xii. III, Pl. XIIA, 10, XIVA, 2.

² It will be noticed that this description agrees with that of Bunbury (Q. J. G. S., XVII, 1861, p. 339), except that he does not appear to have recognised the continuous radial septa, no specimens showing a transverse section having been included in the collection examined by him. Solms Laubach in his Fossil Botany (English translation, p. 366) has adopted a description agreeing in all respects with that in the text above.

³ Etude sur quelques plantes fossiles, en particulier *Vertebraria* et *Glossopteris*, des environs de Johannesburg (Transvaal); Bull. Soc. Géol. de France, 3rd series, XXIV, 349–378 (1896).

completeness of the material at his disposal has led him to overlook the outer sheath connecting the extremities of the radial septa. The analogies he sees between *Vertebraria* and the rhizome of *Sturthiopteris germanica* are consequently unfounded, but the main fact, the connection between *Vertebraria* and *Glossopteris*, remains unaffected.

M. Zeiller in the same paper notices¹ that Dr. Feistmantel's figure of *Sagenopteris longifolia* referred to above, seems to represent a group of fronds at the end of a rhizome, rather than a palmate leaf. He also remarks that Dr. Feistmantel's *Sagenopteris polyphylla* (Pal. Indica, ser. xii, III, pl. XLI A, fig. 4) appears to be the same specimen as that figured by McClelland under the name *Glossopteris acaulis*. I can confirm this suggestion, as after a careful examination of the figures, the specimen, and the registers of the Survey I had already satisfied myself that the specimen described was the same in both cases. This specimen and that forming fig. 3 of the same plate belong to the same species, each represents a group of fronds which individually resemble *Gl. conspicua*, Feist., in shape and venation. The small fragment of stem or stalk preserved in the specimen fig. 3 is only .25 inch long and .1 inch across; it is covered with a layer of carbonaceous material, the outer surface of which shows a longitudinal striation, but no trace of the characteristic *Vertebraria* structure.

I have allowed the specific name *Gl. communis*, Fstm., to stand—although M. Zeiller in the paper under notice has shown that the characters which distinguish *V. indica*, Schimper and *V. communis*, Fstm., may be found in the same frond—as it seems very doubtful how far the distinctions between the species of *Glossopteris* represent true specific differences in the plants as they lived, and it seems convenient to retain the names as descriptive of different types of venation of the fronds.

EXPLANATION OF PLATES.

PLATE I.

A plant of *Glossopteris indica*, Feist., with portion of root-stock attached; two-thirds natural size. The root-stock separated, twice natural size; from Reohal S. Rewah, Lat. $23^{\circ}52'$ Long. $82^{\circ}22'$.

PLATE II.

Fig. 1. *Vertebraria indica* showing ramification by splitting up of the main axis. This specimen shows the usual mode of preservation and appearance of *Vertebraria*, as well as the most common type of ramification; Bajbai, S. Rewah, Lat. $24^{\circ}4'$ Long. $81^{\circ}56'$.

Figs. 2-5. Different views of a fragment of *Vertebraria*, showing radial and transverse septa; from the Aurunga coalfield, Sukri river.

¹ Loc. cit., p. 371.

PLATE III.

Fig. 1. Cast of *Vertebraria*, with the longitudinal and transverse septa represented by cavities ; Aurunga coalfield, Sukri river.

Fig. 2. A specimen showing the longitudinal and transverse septa standing out in relief by the weathering away of the softer matrix ; figured in Pal. Indica, ser. xii, IV, pt. ii, Pl. IV A, fig. 5, same locality as fig. 1.

Fig. 3. Another, smaller specimen showing the same features as fig. 2 ; figured in Pal. Indica, ser. xii, IV, pt. ii, pl. IV A, fig. 9 ; same locality as figs. 1 and 2.

Fig. 4. A fragment preserved in the same manner as pl. II, figs 2-5, but showing part of the outside rind connecting the ends of the radial septa : same locality as Pl. II, figs. 2-5.

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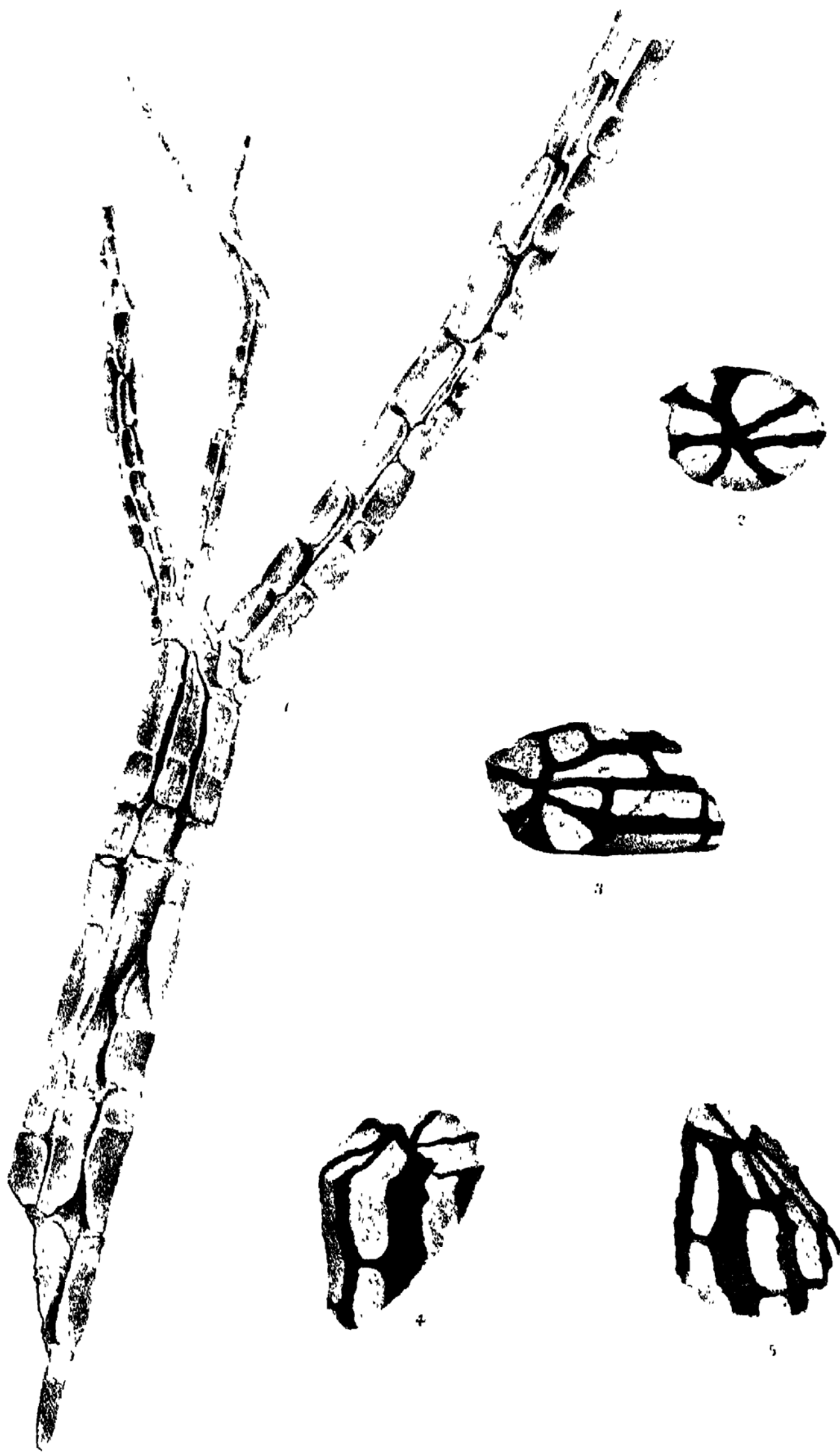


GLOSSOPTERIS COMMUNIS. 7

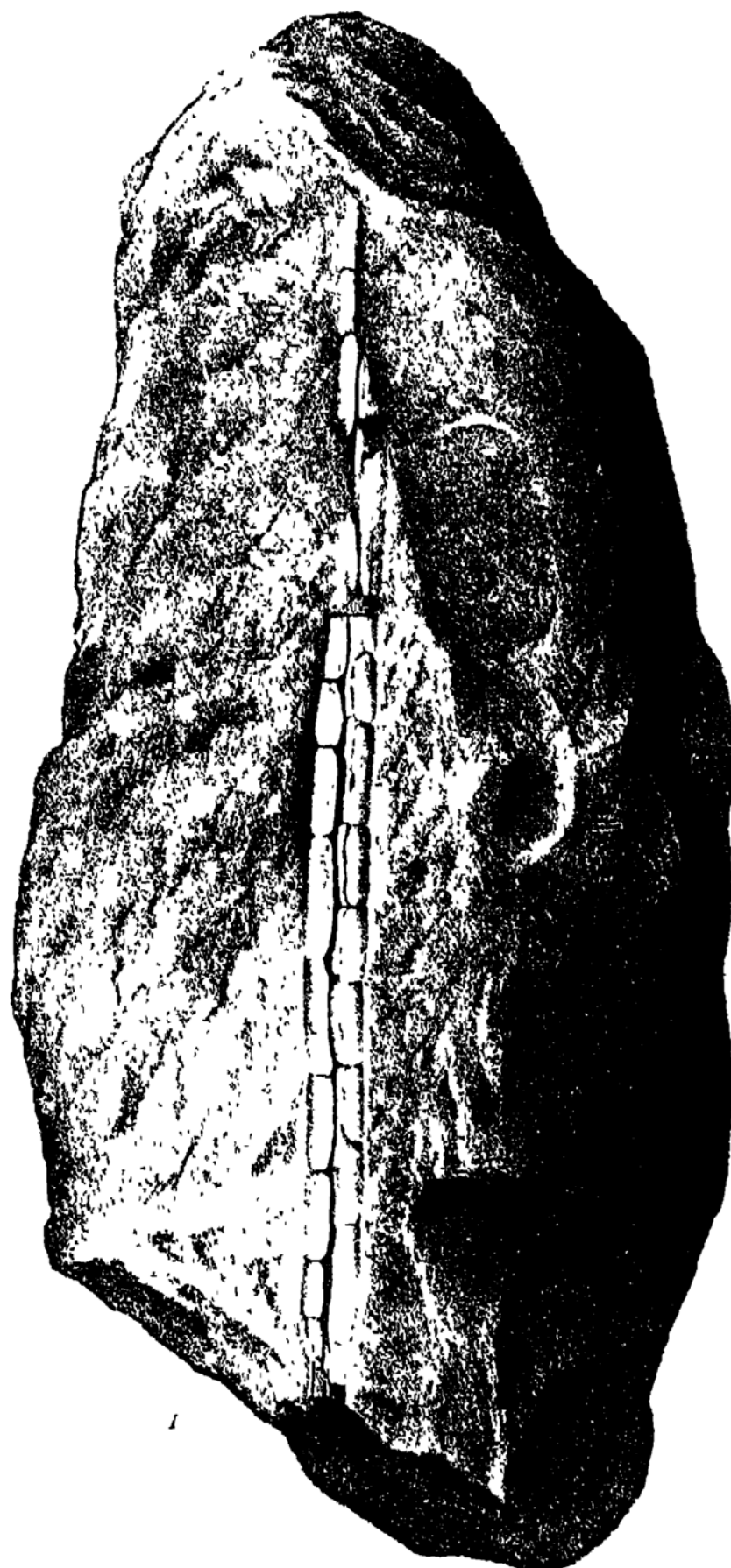
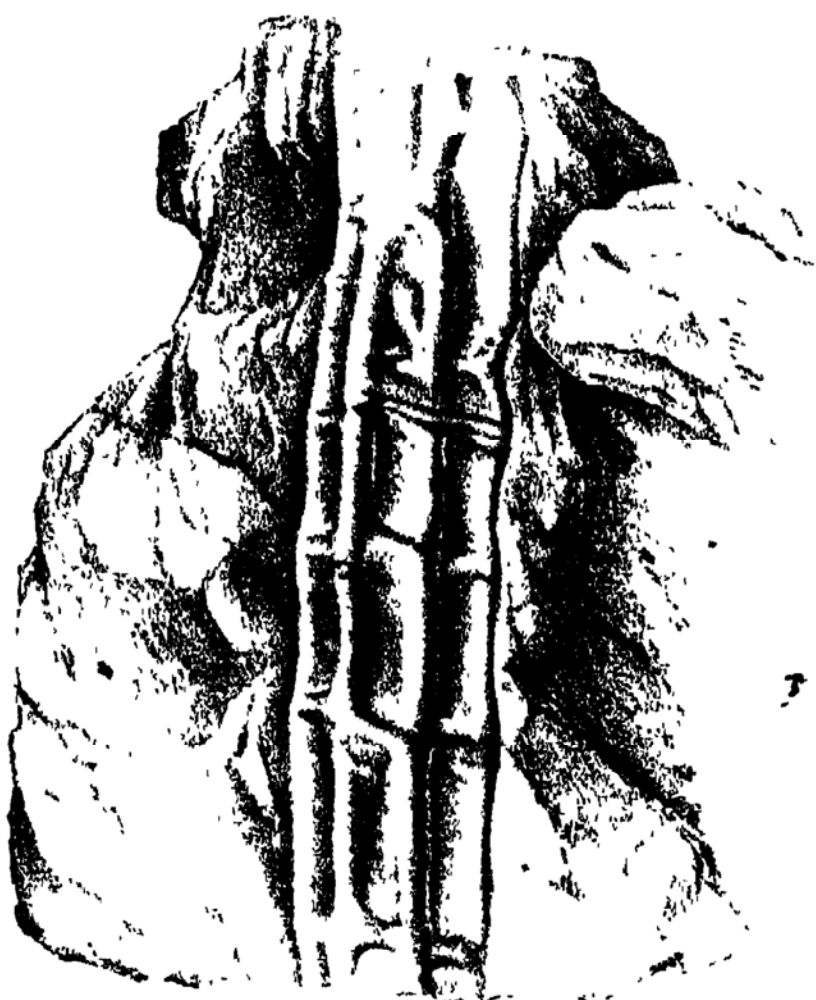
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R D Oldham

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VERTEBRARIA INDICA.



VERTEBRARIA INDICA.

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RECORDS
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THE GEOLOGICAL SURVEY OF INDIA.

Part 2.

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*The Cretaceous Deposits of Pondicherri, by DR. FRANZ KOSSMAT.
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PART I. ON THE STRATIGRAPHY AND FAUNISTIC RELATIONS OF THE CRETACEOUS OF PONDICHERRI.

The cretaceous rocks of Pondicherri, long known in geological literature, had shown numerous peculiarities in their fauna, which were with such difficulty brought into harmony with the then imperfect knowledge of the European cretaceous faunas, that the three distinguished palæontologists, Edw. Forbes, A. d'Orbigny, and F. Stoliczka, who undertook their study came to entirely different conclusions.

Forbes,¹ who had the opportunity of working up the largest collection of Pondicherri fossils made at any time, concluded that in spite of the great number of tertiary and recent molluscan genera, he was dealing with a cretaceous deposit corresponding with the European neocomian. What led him to this conclusion was the occurrence of a great number of ammonites, whose nearest relations he found in the European neocomian; he even went so far as to identify some specimens with species of the lower cretaceous (*Am. juilleti*, Orb., *Am. rouvianus*, Orb.). Besides this the occurrence of numerous *Hamites*, which at that time were only little known in the upper cretaceous, gave an older facies to the cephalopod fauna. The frequent occurrence of gastropod and bivalve types of a later period was explained by Forbes on the supposition that the Indo-Pacific area was their "original habitat, from which they afterwards penetrated into the European seas.

A. d'Orbigny² who, almost at the same time as Forbes, had studied a smaller collection of Pondicherri fossils, came to quite a different conclusion. He considered them to be of upper cretaceous age and in his "Prodrôme de Paléontologie"³ placed the whole of the fauna (also the species described by Forbes) in his étage senonien, an opinion which is proved at present to be the

¹ *E. Forbes*: Report on the Fossil Invertebrata from Southern India collected by Mr. Kaye and Mr. Cunliffe. Trans. Geol. Soc., London, 2nd ser., VII, 1846, pp. 97-174, pl. VII-XIX.

² *Voyage de l'Astrolabe et de la Zélée. I. Paléontologie, Atlas*, pl. I-V.

³ Paris, 1850. Vol. II, p. 211 ff.

correct one. This result is to be traced to the circumstance, that d'Orbigny, from his own observation, knew the fauna of the French upper senonian, which gives the most important basis for the determining of the age of the Indian specimens. Since no correct stratigraphical account was then at their disposal, Forbes as well as d'Orbigny treated the Pondicherri deposits as a whole. Such an account was first given by H. F. Blanford¹ as a result of the geological survey of the district, and the division made by him formed the basis of Dr. Stoliczka's² studies on the Pondicherri fossils. Blanford distinguished two fossil-bearing divisions (1) the "Valudayoor group," which had given by far the greatest number of species described by Forbes, and was thought to be neocomian, and (2) a later division, which in its facies and fauna represented an undoubted equivalent of the Ariyalūr stage of the Trichinopoli district. This latter determination was completely confirmed by F. Stoliczka; but as to the Valudayur stage he thought that he recognised in its ammonite fauna resemblances to the Utatūr stage (cenomanian) of the Trichinopoli district,³ and consequently placed it, in this horizon.

It must have appeared remarkable that the fauna of the lower division of Pondicherri was not so different from that of the typical Ariyalūr stage as it might have been supposed to be, considering the great accepted difference of age between them, but that a great many species were common to the two groups, as Blanford had already put in evidence. This was the case with the cephalopoda, but it was still more striking with the gastropods and bivalves. A series of species which originated in the characteristic bluish shell-sandstone of the Valudayur beds proved to be undoubtedly identical with known Ariyalūr forms, and Stoliczka came gradually to the conclusion "that the extent of the Valudayoor group as being the lowest and about equivalent to the Ootatoor beds must be accepted very cautiously. The larger number from these Pondicherry beds are rather identical with those from the Arrialoore group."⁴ Stoliczka could not come to a complete solution of the question as long as he was compelled to believe in the identity of a larger number of Valudayur and Utatūr ammonites, and thus the Valudayur beds remained a special division belonging to the cenomanian, appearing as such in the "Manual of the Geology of India, 2nd Edition" (Calcutta, 1893, p. 235), and all other isolated deposits standing in near relationship to the Valudayur stage were accordingly assigned to the cenomanian. Some years ago when I began the examination of the fossils collected by Dr. H. Warth in the Trichinopoli district, I was likewise occupied with the question of the age of the Pondicherri beds, and I undertook a journey to London for the special purpose of examining Forbes' original specimens preserved in the collections of the Geological Society. It was soon seen that the formerly accepted conformity of the Valudayur and Utatūr ammonites did not exist, and that the ground upon which the identification of the two deposits rested was removed, an opinion which

¹ H. F. Blanford : On the Cretaceous and other Rocks of the South Arcot and Trichinopoly districts, Madras ; Mem. Geol. Surv. Ind., IV, 1862, p. 156 ff.

² F. Stoliczka : Cretaceous Fauna of Southern India (4 Vols.) Palæontologia Indica. Calcutta, 1865—1873.

³ F. Stoliczka : Cretaceous Fauna of Southern India, Vol. I. (cf. the list, pp. i.—ix.)

⁴ F. Stoliczka : *ibid*, Vol. II, p. 217.

I published, after my return from London, in a paper upon the zoogeographical character of the cretaceous of Southern India.¹

In the winter of 1894-95, Dr. H. Warth² was deputed to reexamine the Pondicherri district, in which his principal task was the collection of fossils for the exact stratigraphical division of the cretaceous deposits. This undertaking was accomplished by Dr. H. Warth in an efficient manner, and he succeeded, in spite of the lack of good exposures and in spite of the exhaustion of the locality, formerly so rich in fossils, in amassing a collection which permitted a correct idea of the succession of the fossil-bearing horizons being attained.

These fossils were transmitted to Professor W. Waagen by Mr. C. L. Griesbach, Director of the Geological Survey of India, by whom I was entrusted with the task of working them out. I may here mention that a similar distinction had been conferred upon me by him in connection with the fossils of the Trichinopoli district. Further, I am indebted to Messrs. Noetling and Warth, who selected these fossils for despatch.

As the number of new, palæontologically important, species is very small in the whole collection, as moreover its principal interest is of a purely stratigraphical nature, I consider it expedient to begin with the geological part and to give the palæontological descriptions as an appendix.

1. THE STRATIGRAPHICAL DIVISIONS OF THE CRETACEOUS OF PONDICHERRI AND THEIR FOSSIL CONTENTS.

Dr. H. Warth distinguished during his researches into the cretaceous deposits of the Pondicherri district six different horizons (A—F), which dip slightly towards the east and are separated from the crystalline region to the west by a band of alluvium. The area which they occupy is rather small (eight miles by four) and moreover mostly covered by arable and garden land.

The horizon A (base) does not come into consideration in our stratigraphical researches, as no fossils are known in it except fossil wood and traces of worms. Thus there remain only the five other horizons, which have produced the whole of the Pondicherri fauna known up to the present time. It has been proved, it is true, by the examination of the fossil material, that the several horizons do not form independent palæontological zones, but that band B and C, as well as band D and E are connected together. Nevertheless they each possess special petrographical characters, which had to be more carefully investigated by Dr. Warth, because it was believed at that time that the Utatúr stage (cenomanian) and Ariyalúr stage (senonian) were represented in the Pondicherri district, and thus it was to be hoped that in one of the horizons the presence of the equivalents of the Trichinopoli stage could be verified.

Of the horizons established by Warth, the two lower (B and C), correspond

¹ F. Kossmat: Ueber die Bedeutung der S. indischen Kreideformation, etc.: Jahrb. k. k. geol. Reichsanstalt, Wien, XLIV, 1894. Pt. 3, p. 461; translated in Rec. Geol. Sur. Ind., XXVIII 1895, p. 41. (The translation of some passages is not quite correct.)

² Dr. H. Warth: The Cretaceous formation of Pondicherry: Rec. Geol. Surv. Ind., XXVIII, 1895, pp. 15-21.

with the Valudayur stage of Blanford, the three upper comprise the bed which Blanford and Stoliczka considered as the equivalent of the Ariyalūr stage. But as, according to the results of the present researches, the Valudayur beds also come within the range of the Ariyalūr stage, the recognizable divisions of the cretaceous in the Pondicherri district can only be designated as substages.

I apply to them the following designations¹ :—

C.—Nerinea Beds=Horizon F of Warth.

B.—Trigonoarca Beds=Horizons D and E of Warth.

A.—Valudayur beds, of Blanford (Anisoceras beds)=Horizons B and C of Warth.

1. Valudayur (Anisoceras) beds ; Horizons B and C of Warth.

These beds have yielded the most numerous and best preserved fossils, among them a great number and variety of ammonite forms, and not only for this reason, but also on account of the still undecided question of age they were the most interesting division of the Pondicherri cretaceous.

The characteristic rock of the Valudayur beds (horizon C) is a very hard, fine grained, calcareous shell-sandstone of bluish or brownish colour, which bears much resemblance to the lumachelle of Garudamangalam ("Trichinopoly marble"). This rock does not form a continuous band, but only occurs in concretionary masses which are embedded in loose sands.

The fossils, mostly small gastropods and bivalves, are so abundant in the rock that one can often make out more than a dozen different species in a hand specimen. Their state of preservation is, as a rule, excellent, the fossils are almost throughout provided with the shell ; the ammonites generally show the pearly layer, and in the other molluscan shells there are very often remains of the original colour.

It is natural that this in every respect remarkable horizon should be almost exhausted by the different collectors, so that of the splendid ammonites which formed the chief ornament of the Forbes collection almost nothing now remains—even Blanford found the formerly numerous species represented by only a few specimens. It was therefore of great importance to me that this deficiency in the new collections was made good by a comparison with the collection described by Forbes.

The species most frequently occurring in the fauna of the Valudayur beds, and found in almost every large rock fragment are the following : *Anisoceras*, *sp. pl.*, *Baculites vagina*, Forb., *Rostellaria palliata*, Forb., *Turritella pondicherrensis*, Forb., *Dentalium arcotinum*, Forb., *Trochus arcotensis*, Forb., *Solariella radiatula*, Forb., *Pholadomya lucerna*, Forb., *Pharella delicatula*, Stol., etc.

The ammonite fauna of the Valudayur beds is characterized by a variety and abundance of species of *Phylloceratidæ* and *Lytoceratidæ* otherwise rarely to be met with, as among 34 species 20 belong to these two groups. Of *Lytoceras*

¹ F. Kossmat: Untersuchungen über die Südindische Kreideformation : Beiträge zur Geologie und Palæontologie Oesterr. Ungarns und des Orients, IX, Heft iii, iv, Wien, 1895, p. 102 (6).

itself 3 subgenera are represented, whilst among the aberrant forms of this family *Anisoceras* and *Baculites* predominate and occur in great abundance. The other ammonite groups are—with the exception of *Pachydiscus*—represented only by one or two species each. (Compare the general list of fossils.)

Much less remarkable, faunistically as well as petrographically, is the lower part of the Valudayur beds (Warth's Horizon B), which consists of yellowish sands and light coloured, fossil-bearing concretions. All the fossils collected by Dr. Warth in this, as it would seem formerly unknown horizon, are identical with species of the typical Valudayur beds (horizon C), and the horizons B and C may therefore unhesitatingly be put together as a single palæontological zone.

As the horizon of the Valudayur beds is easily recognized by its petrographical characters, I made the attempt when investigating the Forbes collection to collate the fossils belonging to those beds. It was thus seen that the species considered by Stoliczka as characteristic of the Utatúr stage appear associated with typical fossils of the Ariyalúr stage, and I think it is not superfluous to enumerate here some examples of the association of Valudayur species in the Forbes collection. I found the following species associated together in one and the same rock specimen :

- (1) *Puzosia rembda*, Forb. (large example), with *Anisoceras indicum*, Forb. -
- (2) *Rostellaria palliata*, Forb. (A), *Pugnellus uncatu*s, Forb. (A), and *Puzosia rembda*, Forb. (small example), with *Baculites vagina*, Forb. (A).
- (3) *Anisoceras largesulcatum*, Forb., with *B. vagina*, Forb. (A).
- (4) *Pachydiscus crishna*, Forb., with *B. vagina*, Forb.
- (5) *Ficulopsis pondicherrensis*, Forb. (A), with *B. vagina*, Forb.
- (6) *Phylloceras surya*, Forb., with *Ptychoceras siph*o, Forb.
- (7) *Ammonites* (n. g.) *brahma*, Forb. (A), with *Ptychoceras siph*o, Forb.
- (8) *Lytoceras indra*, Forb., with *Cerithium scalarioideum*, Forb. (A).
- (9) *L. indra*, Forb., with *Anisoceras subcompressum*, Forb., and *Rostellaria palliata*, Forb. (A).
- (10) *Anisoceras indicum*, Forb., with *Stigmatopygus elatus*, Forb. (A).

[The species marked (A) are found in the typical Ariyalúr stage of Trichinopoli.]

The matrix is invariably the same ; that is, a hard, bluish shell-sandstone, which is filled with the characteristic small molluscan shells of the Valudayur beds. All the ammonites of the Forbes collection and a great number of gastropods and bivalves occur in this horizon. (Compare the general list of fossils.) Also most of the Pondicherri species described by Stoliczka occur, according to his notes on their matrix (bluish or brownish calcareous sandstone), in the same beds. He was however somewhat uncertain as to their horizon. Whilst, it is true, the ammonites are marked "Valudayur Group," the gastropods and bivalves of Ariyalúr type, occurring in the same matrix, are mostly attributed to the Ariyalúr, rarely to the Valudayur, stage, a circumstance which emphasizes Stoliczka's doubts as to the stratigraphical position of the Valudayur beds.

In the following special list of the fossils represented in Warth's collection, I could not indicate the localities one beside the other on account of their great

number (13). I have therefore arranged them in four columns (Rautankupam, Tutipet, Vanur, Pulichapalaia), and marked them with Greek letters as follows.

Fossils of the Valudayur (Anisoceras) beds. Coll. Warth.

	α = Rautankupam	Horizon C
	β = $\frac{1}{4}$ mile NW of Rautankupam	C
Rautankupam	γ = $\frac{1}{2}$ mile NW of "	C
	δ = 1 mile NW of "	C
	ϵ = $\frac{1}{2}$ mile NNE of "	C
	α = 1 mile NNW of Tutipet	C
	β = $\frac{1}{2}$ mile NW of "	C
	γ = NNW of "	C
Tutipet	δ = $\frac{1}{2}$ mile N of "	C
	ϵ = 1 mile N of "	C
	ζ = N of "	C

FOSSILS.	HORIZON C.		HORIZON B.	
	Rautankupam.	Tutipet.	1 mile SE of Vanur.	1 mile SSE of Pulichapalaia.
<i>Lyloceras (Gaudryceras) kayei</i> , F.	...	δ		
<i>Lytoc. (Pseudophyllites) indra</i> , F.	...	β, γ	...	x
<i>Anisoceras indicum</i> , F.	...	α, γ, δ		
" <i>subcompressum</i> , F.	...	δ, ζ		
" <i>tenuisulcatum</i> , F.	...	α, δ		
" <i>undulatum</i> , F.	...	α		
<i>Ptychoceras siphon</i> , F.	...	α		
<i>Baculites teres</i> , F.	ϵ	δ		
" <i>vagina</i> , F.	γ	$\alpha, \gamma, \delta, \epsilon$	x	
" <i>vagina</i> , var <i>otacodensis</i> , Stol.	δ	...		
<i>Pachydiscus egertoni</i> , F.	...	α		
" <i>ganesa</i> , F.	...	δ		
" cf. <i>gollevillensis</i> , Orb.	...	δ		
<i>Desmoceras diphyloide</i> , F.	β	...		
<i>Pugnellus uncatulus</i> , F.	ϵ	γ, δ		
<i>Rostellaria palliata</i> , F.	β	β, δ, ζ		
<i>Athleta purpuriformis</i> , F.	β	α, β, δ		
<i>Uclutilithes radula</i> , F.	β	δ		
" <i>muricata</i> , F.	...	δ		
<i>Lyria granulosa</i> , Stol.	...	δ		
<i>Gosavia indica</i> , Stol.	ϵ	δ		
<i>Turritella pondicherrensis</i> , F.	α	$\alpha, \beta, \gamma, \delta$		
" <i>warthi</i> , Koss.	...	α, β, δ		

FOSSILS.	HORIZON C.		HORIZON B.	
	Rautan- kupam.	Tutipet.	1 mile SE of Vanur.	1 mile SSE of Pulicha- palaam.
<i>Nerita divaricata</i> , Orb.	γ			
<i>Euspira pagoda</i> , F.	ε	γ, δ		
„ <i>rotundata</i> , ? Stol.	...	γ		
<i>Trochus arcotensis</i> , F.	...	α, β, γ, δ		
<i>Solariella radiatula</i> , F.	...	α, β, γ, δ		
<i>Teinostoma cretaceum</i> , Orb.	...	δ		
<i>Ringicula labiosa</i> , F.	...	α		
<i>Trochactæon curculio</i> , F.	γ ...	α		
<i>Bullina cretacea</i> , Orb.	...	α, γ, δ		
„ <i>sp.</i>	...	δ		
<i>Dentalium arcotinum</i> , F.	α, ε	α, β, γ, δ		
„ <i>crassulum</i> , Stol.	...	α		
<i>Corbula parsura</i> , Stol.	...	δ		
„ <i>cf. striatuloides</i> , F.	...	γ		
<i>Næra mutua</i> , Stol.	...	γ	...	×
<i>Corimya pertusa</i> , Stol.	...	δ		
<i>Ceromya subsinuata</i> , F.	ε			
<i>Pholadomya lucerna</i> , Stol.	...	α, γ, δ	...	×
<i>Panopæa orientalis</i> , Stol.	β	...	...	×
<i>Siliqua limata</i> , Stol.	...	γ, δ		
<i>Pharella delicatula</i> , Stol.*	...	α, γ, δ	...	×
<i>Tellina pondicherrensis</i> , F.	...	δ		
„ <i>forbesiana</i> , Koss.	...	α, β		
<i>Baroda elicita</i> , Stol.	α	...	...	×
<i>Cardium cf. pullatum</i> , Stol.	...	γ		
<i>Protocardium bisectum</i> , F.	α	δ		
<i>Lucina fallax</i> , F.	...	δ		
<i>Yoldia striatula</i> , F.	...	γ		
<i>Axinea subauriculata</i> , Orb.	...	β, δ		
<i>Macrodon yapeticum</i> , F.	...	α		
<i>Trigonoarca galdrina</i> , Orb.	...	α, δ ?		
„ <i>abrupta</i> , F.	γ			
<i>Modiola polygona</i> , F.	α	α		

* A fine specimen found three quarters of a mile SE of Wottai, together with *Turritella cf. pondicherrensis*, Forb., Horizon C.

FOSSILS.	HORIZON C.		HORIZON B.	
	Rautan- kupam.	Tutipet.	1 mile SE of Vanur.	1 mile SSE of Pulich- palaiam.
<i>Modiola flagellifera</i> , F. . . .	...	γ, δ		
<i>Pinna arata</i> , F.	...	ϵ		
<i>Exogyra ostracina</i> , Lam. . . .	β	α		
<i>Alectryonia unguolata</i> , Schl. . .	α, β	δ	x	
<i>Anomia</i> sp.	...	α		
<i>Lunulites</i> sp.	...	α		
<i>Stigmatopygus elatus</i> , Forb. . .	γ			
<i>Serpula filiformis</i> , Sow	...	β		

2. *Trigonoarca* beds (horizons D and E of Warth, Arrialoore Group of Blanford, in part).

The *Trigonoarca* beds, which I have thus named on account of the abundance of *Trigonoarca galdrina*, Orb., are easily distinguished from the underlying *Anisoceras* beds by their petrographical structure.

They consist in their lower parts (horizon D) of very soft, friable sand and clay, of yellowish white colour, which preserve the fossils for the most part in the shape of casts. Ammonites are very rare, and many of the small gastropod and bivalve types which characterize the Valudayur beds have disappeared, probably because the rock is not favourable for their preservation. On the other hand *Nautilus* is found pretty often, whilst among the bivalves certain genera, especially *Ostrea* (*Exogyra*, *Alectryonia*) and *Trigonoarca*, appear in great numbers. The infilling of the fossils is very often a dark brown to black phosphate of lime, which is frequently also imbedded in the light coloured sand in the shape of irregular concretions.

Shark's teeth are not unfrequently met with in this horizon.

The upper *Trigonoarca* beds (horizon E), which, for example, are well developed in the neighbourhood of Rayapudupakam, likewise contain numerous phosphatic concretions in a fairly soft sandy clay matrix, which can scarcely be distinguished from that of the Ariyalur beds near Otacod. In some places concretionary layers of hard, fine grained sandstone are met with in the horizon E, containing numerous, well preserved bivalves (*Trigonoarca galdrina*, Orb.) and sometimes show sections of corals (*Cyclolites filamentosa*, Forb.).

The distinction between Warth's horizons D and E is often rather difficult on account of the similarity of the structure of the rock composing them. Further, one finds in comparing the faunas of the D and E localities, that all the more abundant and remarkable species are common to both, and that on the whole only three of the rarer species of gastropods of the horizon E have not yet been recognized in the lower beds of Pondicherri.

I am therefore quite justified in regarding the two horizons D and E as a stratigraphical unit. Nevertheless I have made use in the following list of all the localities indicated by H. Warth, so that the opportunity is offered to every one to compare the faunas of each locality and to become convinced of their concordance.

The following species belong to the more abundant fossils of the Trigonarca beds: *Turritella breantiana*, d'Orb., *Nerita divaricata*, d'Orb., *Cypræa*, sp. pl., *Rostellaria palliata*, Forb., *Macrodon japeticum*, Forb., *Trigonarca galdrina*, d'Orb., *Exogyra ostracina*, Lam., *Alectryonia unguolata*, Schloth. Specimens of silicified wood, which had evidently floated from the neighbouring land, are also not uncommon.

The Trigonarca beds are also represented in the Forbes collection by remarkable fossils, which are all imbedded in a light yellowish, soft, sandy matrix. Among them are to be found, for example, *Turritella breantiana*, d'Orb., *Cypræa kayei*, Forb., *C. cunliffei*, Forb., *C. newboldi*, Forb., *Euspira pagoda*, Forb., *Spondylus calcaratus*, Forb., and some other species.

Blanford collected several fossils in the Trigonarca beds, especially in the neighbourhood of Rayapudupakam and Saidarampet. The ammonite *Lytoceras (Pseudophyllites) indra*, Forb., formerly known only from the Valudayur beds, is of special importance among the fossils collected by him at Rayapudupakam. Stoliczka doubted the correctness of this locality, and gave to the specimen figured on pl. LVIII, figure 2, only the locality indicated "Pondicherry." I had the opportunity of examining this specimen and found that not only the soft, yellowish, sandy matrix, but also a *Turritella breantiana*, d'Orb. (not known in the Valudayur beds), attached to it shows the correctness of Blanford's locality.

The number of species which Stoliczka described from the Trigonarca beds (mostly with the observations "soft, whitish sandstone," Ariyalūr beds) is not very large; the greater number of them are also represented in Warth's collection.

Fossils of the Trigonarca beds. Coll. Warth.

	$\alpha = \frac{1}{4}$ mile W of Rautankupam	.	Horizon D
<i>Rautankupam</i>	$\beta = \frac{1}{4}$ mile WNW of "	.	" D?
	$\gamma = 1$ mile NNE of "	.	" E?
<i>Tutipet</i>	$\alpha = \frac{1}{2}$ mile WSW of Tutipet	.	" D
	$\beta = \frac{1}{4}$ mile WSW of "	.	" D
	$\gamma =$ W Slope of Tutipet ridge	.	" D?
<i>Karasur</i>	$\alpha =$ Karasur	.	" D
	$\beta = \frac{1}{4}$ mile NNW of Karasur	.	" D
	$\gamma = \frac{1}{2}$ mile NNW of "	.	" E
	$\delta = \frac{1}{4}$ mile N of "	.	" D
	$\epsilon = \frac{1}{2}$ mile N of "	.	" D
	$\zeta =$ Karasur?	.	" E?
<i>Rayapudupakam</i>	$\alpha =$ Rayapudupakam tank	.	" E
	$\beta =$ W. of Rayapudupakam	.	" E
	$\alpha = 1$ Saidarampet	.	" E?
<i>Saidarampet</i>	$\beta = 1$ mile N of Saidarampet	.	" E
	$\gamma = 1$ mile NW of "	.	" E?
	$\delta = \frac{1}{4}$ mile WNW of "	.	" E?
	$\epsilon =$ Saidarampet?	"	" E?

	Rautan- kupam.	Tutipet.	Karasur.	Raya- pudu- pakam.	Sai- daram- pet.	½ mile N of Wat- tampa- laiaam (Horiz. E.)
<i>Otodus</i> sp. pl.	a	...	δ			
<i>Am.</i> (n. g.) <i>brahma</i> , F.	...	...	...	...	ε	
<i>Pachydiscus gollevillensis</i> , Orb.	a					
<i>Baculites vagina</i> , F.	a	...	δ	ε		
<i>Nautilus</i> n. sp. (<i>clementinus</i> , Blanf.)	...	...	β	...	β	
<i>Nautilus sublævigatus</i> , Orb. var.	...	...	ζ			
<i>Belemnites fibula</i> , F.	β		✓			
<i>Pugnellus uncatus</i> , F.	a					
<i>Rostellaria palliata</i> , F.	a	a	...	a		
<i>Cypræa kayei</i> , F.	...	...	...	a		
„ <i>cunliffei</i> , F.	a					
„ <i>newboldi</i> , F.	...	a	δ	a		
<i>Gosavia indica</i> , Stol.	...	...	...	a		
<i>Volutilithes muricata</i> , F.	a					
„ <i>radula</i> , F.	...	...	ζ			
<i>Murex fluctuosus</i> , F.	a					
<i>Trichotropis</i> sp.	...	a				
<i>Cerithium karasurense</i> , Koss.	...	...	a			
<i>Turritella breantiana</i> , Orb.	...	a	...	...	ε	
„ cf. <i>pondicherrensis</i> , F.	...	...	...	a	a	
<i>Scala</i> cf. <i>turbinata</i> , F.	...	a				
<i>Euspira pagoda</i> , F.	a	...	...	...	...	x
<i>Nerita divaricata</i> , Orb.	...	...	β	...	ε	
<i>Euptycha larvata</i> , Stol.	...	...	...	a		
<i>Ceromya subsinuata</i> , F.	...	...	β	...	a	
<i>Pholadomya lucerna</i> , F.	a, β	β				
<i>Panopæa orientalis</i> , F.	...	...	...	a		
<i>Cyprina cristata</i> , Stol.	a					
<i>Hippagus æmilianus</i> , Stol.	a					
<i>Macrodon japeticum</i> , F.	a	α, β, γ	β, γ	...	ε	
<i>Trigonoarca galdrina</i> , F.	a	α, β	β, γ	a	α, β	
„ <i>abrupta</i> , F.	...	...	...	a		
<i>Nucula</i> sp. ?	...	β				
<i>Protocardium bisectum</i> , F.	...	...	...	...	β	
<i>Spondylus calcaratus</i> , F.	a					
„ <i>ariyalurensis</i> , Stol.	...	a				

	Rautan- kupam.	Tutipet.	Karasur.	Raya- pudu- pakam.	Sai- daram- pet.	½ mile N of Wat- tampa- laiam (Horiz. E.)
<i>Spondylus lamellosus</i> , Koss.	α	α	...	...	ε	×
<i>Plicatula septemcostata</i> , F.	...	α				
<i>Exogyra ostracina</i> , Lam.	α, β, γ	...	β	α, β	ε	×
<i>Ostrea</i> sp.	α, β					
<i>Alectryonia unguolata</i> , Schl.	α	α	γ	α, β	α, γ, ε	
<i>Terebratula arabilis</i> , F.	α	α				
„ <i>biplicata</i> , Sow.	α					
<i>Hemiaster pullus</i> , Stol.	α					
„ <i>tamulicus</i> , Koss.	α					
<i>Cyclolites filamentosa</i> (?) F.	...	β				
Fossil wood	...	α	ε	...	γ, δ	

3. *Nerinea* beds (Horizon F of Warth, Arriyaloor group of Blanford, in part.)

The *Trigonoarca* beds are overlaid by a yellowish, very calcareous, coarse grained sandstone, which contains here and there limestone nodules, and forms the only continuous hard bed in the Pondicherri cretaceous. Blanford and Warth mention peculiar cylindrical bodies occurring in it. The fauna of this bed is distinguished, according to the species which I have before me, principally by the presence of large specimens of *Nerinea*, *Nautilus*, and vast numbers of *Foraminifera* (especially *Orbitoides*), filling the hard matrix of the greater fossils.

Some species (corals, *Teredo*, *Ostrea*) occur in the loose sands which, according to Warth's communication, overlie the hard, calcareous stratum.

The horizon, called here *Nerinea* beds, was already known to Mr. H. F. Blanford (although no *Nerinea* seems to have been found by him), but he united it with some other fossiliferous beds (called in this paper *Trigonoarca* beds) as one division, which he identified with the Ariyalūr stage. The establishment of the *Nerinea* beds as a separate horizon is practically the only difference between Blanford's scheme of the Pondicherri cretaceous and that adopted in this paper.

Nautilus danicus, Schloth., *N. serpentinus*, Blanford, and *N. sphaericus*, which were described by Blanford from Rayapudukapam and Saidarampet, may with certainty be ascribed to the *Nerinea* beds, occurring in these localities above the *Trigonoarca* beds, the more so as from Saidarampet, from Warth's horizon F, the two latter species are actually lying before me.

This uppermost fossil-bearing horizon is very little represented in Forbes's collections; to it belong probably *Nautilus sphaericus*, F., *Caryophyllia arcolensis*, F., and the peculiar *Nautilus (Aturia) delphinus*, F., which is not to be found in the more recent collection.

Fossils of the Nerinea beds. Coll. Warth.

<i>Nautilus serpentinus</i> , Blanford	.	Saidarampet.
„ <i>sphaericus</i> , Forbes	.	Saidarampet, 1½ mile SSE of Valudayur (Usteri canal), E of Wottai ?
„ <i>tamulicus</i> , Koss.	.	Saidarampet, Kadaperikupam ?
<i>Nerinea</i> sp.	.	1½ mile SSE of Valudayur (Usteri canal).
<i>Cerithium</i> cf. <i>karasurense</i> , Koss.	.	Saidarampet.
<i>Teredo glomerans</i> , Stol.	.	1 mile SSE of Valudayur (Usteri canal), ½ mile SW of Tutipet, ¼ mile WSW of Trumbai.
<i>Ostrea</i> sp.	.	Saidarampet, ¼ mile NW of Trusitambalam.
<i>Cyclolites conoidea</i> , Stol.	.	Saidarampet, ½ mile SW of Tutipet.
<i>Turbinolia arcotensis</i> , Forbes	.	1 mile SSE of Valudayur (Usteri canal), ¼ mile NW of Trusitambalam.
<i>Orbitoides</i> sp.	.	SSE of Valudayur; Saidarampet (Usteri canal).
<i>Amphistegina</i> sp. ?	.	SSE of Valudayur (Usteri canal).

4. Faunistic affinities between the three divisions of the Pondicherri cretaceous.

The faunistic isolation of the Valudayur beds, as compared with the upper beds, is not so great as was formerly assumed, and the above lists of fossils show a pretty large number of species which extend from Warth's horizon B, to the horizon E, or, in other words, from the lower Valudayur beds to the upper Trigonoarca beds. Out of 46 species from the Trigonoarca beds in Warth's collection, 18 are also known in the Valudayur beds, among them very characteristic examples, as *Am. brahma*, *Baculites vagina*, *Pugnellus uncatu*, *Rostellaria palliata*, etc. *Am. brahma*, which occurs in the shell sandstone of the Valudayur beds associated with species of *Anisoceras* and *Ptychoceras siph*, was found in a rock specimen from Saidarampet with a phosphatized cast of *Macrodon japeticum* and a *Turritella breantiana*. *Lytoceras indra*, of which Forbes met with numerous specimens from the Valudayur beds and which was also found by Warth in the horizon B, was collected by Blanford in the Trigonoarca beds of Rayapudupakam. The most abundant species of the latter beds, as, for example, *Trigonoarca galdrina*, *Macrodon japeticum*, *Exogyra ostracina*, *Alectryonia unguolata*, are also not unknown in the lower beds, and the similarity would be still greater, if small gastropods and bivalves, which are found so abundantly in the Valudayur beds, were more suitable for preservation in the Trigonoarca beds.

But, in any case the fact of greatest importance is that three of the four ammonites known in the Trigonoarca beds are identical with species of the Valudayur beds. The fourth is nearly related to *Pachydiscus crishna*, Forb., so that the animal group, upon which the most sharply defined zonal divisions are generally based, gives here no aid in making a distinction founded upon palæontological and stratigraphical grounds. The distinction between the two beds above-named seems on the whole to be traceable to their different facies, and it is there-

fore not very probable that they will be easily recognized outside the Pondicherri district.

The fauna of the Nerinea beds, which certainly up to the present time is very little known, seems to have a much more independent position.

2. RELATIONS BETWEEN THE CRETACEOUS DEPOSITS OF THE PONDICHERRI AND TRICHINOPOLI DISTRICTS.

1. Relations to the Utatúr stage (Lower division of the cretaceous of Trichinopoli).

Stoliczka tried to show that the ammonite fauna of Pondicherri did not indicate neocomian, but was much more nearly related to that of the Utatúr stage, and even had a number of species in common with it. The Valudayur beds were on that account looked upon as their equivalent division, that is to say, as cenomanian. It is therefore necessary to examine the species, on which this determination of the age, corresponding so little with the otherwise intimate connection of the Ariyalúr and Valudayur beds, was based. Such a comparison between the formerly identified species of the Utatúr and Valudayur beds can only be very briefly indicated in the following statement; for details I must point to the revision of the cretaceous fauna of Southern India, of which the first part has already appeared.¹ :—

A.—VALUDAYUR BEDS.

Phylloceras nera, Forb.

Phylloceras forbesianum,
d'Orb.

B.—UTATÚR STAGE.

Phylloceras velledæ, Mich., with which Stoliczka (Records, I., p. 34) identified the *Phyll. nera*, possesses more inflated sides, less complicated sutures, and shows no constrictions in the umbilical region (cf. Kossmat: Untersuchungen über die s. ind. Kreide, p. 109).

With *Phyll. forbesianum*, Orb. (= *rouyanum*, Forb., non d'Orb.) was identified a form from the Utatúr stage by Stoliczka, and with some reservation by myself (cf. Kossmat: loc. cit., pp. 111, 158). Nevertheless there are some differences which appear to be of specific importance. The Utatúr examples are more strongly inflated and do not show the funnel-shaped depression around the umbilicus so distinctly; the saddles of the sutural line are more prominent than in the Pondicherri species, and the siphonal lobe is simply lancet-shaped, whilst it is greatly indented in *Phyll. forbesianum*. My attention was drawn to these differences only when Mr. J. F. Whiteaves had sent me from the Nanaimo stage of

¹ F. Kossmat, Untersuchungen über die südindische Kreideformation, I Theil: Beiträge zur Geologie und Paläontologie Österreich-Ungarus und des Orients. Herausgegeben von Prof. Dr. W. Waagen, IX, Heft iii, iv, Wien, 1895.

the Georgia Straits, British Columbia, a *Phylloceras* which corresponds well with the Valudayur species but is to be distinguished from the Utatúr species on account of the characters mentioned of the latter.

Lytoceras (*Gaudryceras*)
varuna, Forb.

Stoliczka's specimen differs in the absence of a distinct umbilical wall, and in the larger size of the second lateral saddle (*Lyt. odiense*, Kossmat, loc. cit., p. 129).

Lyt. (*Gaudryceras*) *kayei*,
Forb.

Lyt. kayei, Stol. = *Lyt. vertebratum*, Kossm., loc. cit., p. 126) is distinguished by its rapidly increasing whorls and the completely flattened periphery in the middle period of growth.

Lyt. (*Tetragonites*) *cala*,
Forb.

Lyt. cala, Stol. (= *L. kingianum*, Kossm., loc. cit., p. 136) increases rapidly, is much more involute than the Pondicherri species and has an oval (not quadrate) cross section.

Hamites (*Anisoceras*) *indicum*, Forb.

= *An. subcompressum*, Stol.; from Odiam; only mentioned but not figured (Kossmat: loc. cit., p. 145).

Ham. (*Anisoceras*) *subcompressum*, Forb. (*An. indicum*, Stol.)

The examples from Odiam are not flattened on the sides, and are without constrictions (Kossmat: loc. cit., p. 145).

Hamites (*Anisoceras*) *neréis*,
Forb.

An. neréis, Stol., is distinguished from the Pondicherri species by its cross section and sculpture. The groove on the periphery is not structural, as in the type, but occurs only through the removal of the siphon, for the ribs run uninterruptedly over the periphery in many places (Kossmat: loc. cit., p. 148).

Baculites teres, Forb.

The example from Odiam is distinguished by the possession of annular swellings and is very probably not a *Baculites*, but a fragment of a *Hamites* (*Ptychoceras*?) (Kossmat: loc. cit., p. 154).

Desmoceras diphyloide, Forb.

Stoliczka describes this species from Odiam, but I have only before me examples, which come from the white sandstone of the Ariyalúr stage from Otacod.

Puzosia rembda, Forb.
(synon. *P. durga*, Forb.).

Ammonites durga, Stol., from the Utatúr stage is distinguished by the difference in the form of the constrictions, by the absence of a keel, and by the more complicated suture.

Belemnites fibula, Forb

B. fibula, Blanford, is quite different from the Pondicherri species (which does not occur in the Valudayur beds, but in the Trigonoarca beds) in the character of its cross-section (cf. the palæontological part of this paper).

Desmoceras jama, Forb.

The large, fine ammonites, which were identified by Stoliczka first with *Desmoceras beudanti*, d'Orb., then with *D. jama*, cannot be compared with this small, unornamented form, of which it cannot be said with certainty, whether it is a typical *Desmoceras* or a *Puzosia*.

Natica munita, Forb.

Vanikoro munita, Stol., is quite distinct from the Pondicherri species. In the latter the flat band is bordered along the suture by a sharp edge, near which the sides are slightly concave. Moreover the mouth is considerably widened laterally, as in *Gyrodes tenellus*, Stol.

Tellina pondicherrensis, Forb.

Baroda pondicherrensis, Stol., is distinguished by the presence of radiating striæ and by the stronger concentric sculpture.

Protocardium bisectum, Forb.

The example figured by Stoliczka from Monglepady appears to be identical with the Pondicherri species, but it is to be observed that the *P. bisectum* reaches to the upper Trigonoarca beds, that is beds which undoubtedly belong to the Ariyalûr stage.

Trigonoarca gamana, Forb.

Stoliczka's example from the Utatûr stage is very contracted anteriorly, whilst in Forbes's original specimen the lower margin is parallel with the hinge line.

There are other species besides, which are said to occur in both the Ariyalûr and Utatûr stages of the Trichinopoli district; for example, *Lucina fallax*, Forb., *Solariella radiatula*, Forb., *Leptomaria indica*, Forb. (the identity of the specimens from the Ariyalûr stage with those from Pondicherri is only certain in the case of the two last named species). One Pondicherri species, *Axinea cardioides*, d'Orb., is mentioned as occurring in the upper Trichinopoli beds of Serdamangalam, as well as in the Utatûr stage. The ammonites are in the first place the chief factors in the solution of the question, and it has been shown in the revision, the results of which I have briefly mentioned above, that of the twelve formerly identified species, ten are certainly different, one cannot be taken into account, as it has not been figured and the other comes only from the Ariyalûr, not from the Utatûr stage.

But what is of greater weight than all this, is a circumstance of quite another kind, namely, the complete absence of all characteristic Utatúr species and genera in Pondicherri. Although the ammonite fauna of the Valudayur beds was so extraordinarily rich, not a single *Acanthoceras*, nor *Schloenbachia*, nor *Turritiles*, nor *Hamites* of the group of *H. armatus*, Sow., nor *Puzosia* of the group of *P. planulata*, Sow., etc., were found in it—all groups predominating in the Utatúr. What we find in Pondicherri, besides *Phylloceras* and *Lytoceras*, are chiefly species of *Pachydiscus* and other ammonite types of the uppermost cretaceous.

2. Relations to the Trichinopoli stage.

The ammonite fauna of the Valudayur beds is quite different from that of the Trichinopoli stage; but on the other hand, many nearly related, or even some identical species are found among the gastropods and bivalves. But as a study of the list of fossils shows, these are almost throughout such forms as extend upwards unchanged into the Ariyalúr stage in the Trichinopoli district. On the whole the boundary between the two groups is somewhat uncertain, and still requires some corrections. Typical species of the Trichinopoli group are entirely absent in the Pondicherri fauna, and this circumstance is so much the more important as, in consequence of the great similarity in the facies of the lower Trichinopoli stage and that of the Valudayur beds, the fauna is for the greater part composed of the same genera. Among the beautiful molluscs of the bluish lumachelle (shell-sandstone) of Garudamangalam the genera *Pugnellus*, *Solariella*, *Trochus*, *Turritella*, *Euspira*, *Dentalium*, *Bullia*, etc., play the same rôle as in the Valudayur beds, and even the species belonging to these genera resemble each other. In spite of this, cases of true identity are very rare.

3.—COMPARISON BETWEEN THE CRETACEOUS BEDS OF PONDICHERRI AND THE ARIYALÚR STAGE. (UPPER DIVISION OF THE TRICHINOPOLI CRETACEOUS.)

1. Valudayur (*Anisoceras*) beds.

Four characteristic species of the Ariyalúr stage are found in the ammonite fauna of this division, namely, *Pachydiscus egertoni*, *Amm. (n. g.) brahma*, *Desmoceras diphyloide*, *Baculites vagina*, var. *utacodensis*; in other respects also the two groups are conspicuous by the presence of certain types of ammonites as, for instance, certain *Pachydiscus* forms, and by the absence of others, which are very important in the Utatúr and Trichinopoli stages. The ammonite fauna of the Ariyalúr beds is, it is true, not very varied, and therefore does not offer many points of comparison.

The rich gastropod and bivalve fauna is, as the general list shows, almost perfectly identical with that of the Ariyalúr stage, for which reason Stoliczka began to doubt the accuracy of his earlier conception based on the ammonites. Two localities, Parcheri and Kalligadi, which lie on the boundary line between the Trichinopoli and Ariyalúr stages and were first ascribed to the former, show such a striking similarity of their fauna to that of the Valudayur beds, that they may be completely identified with them. In Parcheri *Næra mutua*, Stol.,

Pholodomya lucerna, Forb., *Siliqua limata*, Stol., *Pharella delicatula*, Stol., and *Pugnellus uncatulus*, Forb., occur, besides a few other species. Still greater is the analogy in Kalligadi, which also seems to have in the facies of its fossils great resemblance to the Valudayur beds (Stoliczka, Cret. S. India, Vol. II., p. 96), and as well as these must belong to the Ariyalūr stage.

Warth's horizon B., the base of the Valudayur beds, already contains a true Ariyalūr fauna, and affords a strong proof of the accuracy of the decision come to as to age of the beds.

2. *Trigonoarca* beds.

The great similarity between the Ariyalūr stage and the Pondicherri beds is quite as distinctly recognizable in this division, whose gastropod and bivalve fauna is almost completely identical with that of the former. This similarity is the more remarkable, as the argillaceous sands which characterize the higher Ariyalūr beds also predominate in the *Trigonoarca* beds. The similarity is so great that specimens from Ariyalūr, etc., can often not be distinguished by their matrix from examples from Pondicherri. In the Trichinopoli district peculiar argillaceous beds occur, full of numerous sharp casts of bivalves, which, according to Blanford (Mem. Geol. Surv. India, IV, p. 135), constitute a peculiar feature of the Ariyalūr stage. According to the description, there is no doubt that these argillaceous sands are the same as those occurring in the *Trigonoarca* beds of Rautankupam and Tutipet, where they contain numerous casts of *Trigonoarca galdrina*. The soft yellowish white sands of Otacod, which alternate with these argillaceous sands are again indistinguishable from the sands occurring in the localities of the Pondicherri district mentioned above, where they are also in close relationship with the argillaceous beds. This striking similarity of the facies and fauna could not escape the attention of Blanford and Stoliczka, and therefore we find this horizon always given as the equivalent of the Ariyalūr stage. It is a pity that the latter could not be so distinctly subdivided in the Trichinopoli district as the corresponding beds in Pondicherri, but it seems that there also the localities corresponding in their fauna to the Valudayur beds occur somewhat lower in the series than the others ; that, for example, the beds of the localities Parcheri, Kalligadi, Karapadi, lying at the base of the Ariyalūr stage, agree best with the Valudayur beds, whilst the stratigraphically higher localities Ariyalūr and Otacod are to be correlated with the *Trigonoarca* beds by their facies and in their fauna. But as the faunas of these two horizons in the Pondicherri district evidently blend into one another, so also is this the case in the Trichinopoli district. *Ammonites brahma*, *Baculites vagina*, var *otacodensis*, and numerous gastropods and bivalves of the Valudayur beds occur also in the higher beds of the Ariyalūr stage immediately under the massive sandstone complex of the middle zone (Blanford, p. 138), which has yielded no fossils except some reptilian bones.

3. *Nerinea* beds.

Ammonites are absent in this division but, besides large examples of *Nerinea*, some species of *Nautilus* occur, among the latter a very interesting European form, *Nautilus danicus*, Schloth. Foraminifera, especially *Orbitoides*, appear in

vast numbers and fill the matrix of the larger fossils. Thus the analogy with the beds near Niniyur (Trichinopoli district), where *N. danicus* and *Orbitoides* are found, and ammonites are absent, is apparent.

In the Trichinopoli district, as H. F. Blanford pointed out, the Niniyur beds are distinctly separated from the fossiliferous strata near Ariyalūr by the massive sandstones mentioned above. Almost all fossils are peculiar to them and completely different from those of the typical Ariyalūr beds, a difference which is so apparent that it had already been observed by Mr. H. F. Blanford before the fauna had been studied in detail and looked upon as a matter of great importance. From the absence of ammonites and the occurrence of *Nautilus danicus* he concluded that the Niniyur beds represent the topmost division (danian) of the cretaceous system, a view which has proved to be the correct one. But as he did not formally make these beds a separate division, the Niniyur fossils have been dealt with in Stoliczka's Memoir simply as Ariyalūr fossils, so that the significance of this horizon has become less striking. H. Leveillé, who did not study these beds in the field, proposed, therefore, to give them the name Niniyur stage.¹ A point of great importance, which urgently needs explanation, is the appearance of large specimens of *Nerinea* in the beds of Niniyur (cf. Stol. II., p. 306, 301, 227, 221), which Blanford and Stoliczka have repeatedly drawn attention to, and these specimens are named in some places *Nerinea blanfordiana*. But in the description of this species only Maravattur and Paruli (Utatūr group) are mentioned as localities, whilst not a single *Nerinea* from Niniyur has been described. It seems as if there were some mistake here, the more so, as in different places examples of *Cypræa* in Niniyur have been expressly mentioned, but these also do not appear in the description of the species of this family. But if even the examples of *Nerinea* from Niniyur could be proved to be identical with those of the *Nerinea* beds, it would not be advisable to consider the two horizons as equivalent without further investigation. In the Trichinopoli district the Niniyur beds are separated from the true Ariyalūr beds by the abovementioned thick unfossiliferous formation, whilst in Pondicherri the *Nerinea* beds lie immediately above the equivalent of the typical Ariyalūr beds. For this reason it is quite possible that they correspond to the unfossiliferous division. The fact that species occur, which are also known in the lower beds (for instance, *Nautilus sphæricus*, *Teredo glomerans*) speaks in favour of this view, according to which the *Nerinea* beds would lie on the stratigraphical boundary between the Niniyur and Ariyalūr beds.

4. Conclusions.

From what has been said above it follows that the whole of the cretaceous series of Pondicherri falls completely within the Ariyalūr stage of Blanford, and that with great probability it begins with the same horizon as the latter (beds of

¹ H. Leveillé : Géologie de l'Inde Française. Bull. Soc. Géol. de France. 3me Serie, XVIII, 1889, p. 144 ff. ; cf. W. T. Blanford : On the papers of Dr. Kossmat and Dr. Kurtz, and on the ancient geography of Gondwanaland. Rec. Geol. Surv. Ind., XXIX, 1896, p. 51, referring to a passage in my paper, Jahrb. k.k. geol. Reichs Anstalt, 1894, where, when speaking shortly on the divisions of the Trichinopoli cretaceous, I only quoted the paper of Leveillé in connection with the Niniyur beds.

Parcheri, Kalligadi, etc.). From this results the interesting fact of a true overlap of the Ariyalūr stage, for which also many other proofs are forthcoming.¹

Even in the Trichinopoly district the Ariyalūr stage overlaps the older strata and lies, for example in Olapadi, immediately upon the Utatūr group, and for a considerable extent even on the crystalline rocks. In the northern part of the Trichinopoly district the cretaceous disappears under the alluvium of the Vellar river; reappears in the Viruddhāchallam area—there also the Ariyalūr stage only is present—is then again invisible, to reappear finally in the Pondicherri district once more in rich development.

This overlap of the Ariyalūr stage is of considerable interest, for it is repeated in areas far distant from India and seems to be of great importance in the Pacific area. It will probably be found in the highlands of Assam (N. E. Bengal), but I will not treat of this area whose cretaceous fauna, according to Stoliczka's opinion² bears a very great resemblance to that of Pondicherri, as the fossils belonging to it will be open to a more minute research in the near future.

III.—THE AGE OF THE PONDICHERRI BEDS.

On account of the recognized similarity of the Pondicherri deposits to the Ariyalūr stage, the determination of the age of the former, that is, the comparison with the European cretaceous deposits is proportionally an easy task, in the fulfilment of which the numerous ammonites are of special use. Of the latter very many are found, in the Valudayur beds, which are nearly related to species of the European senonian, while two species appear to agree exactly with such. These are: *Pachydiscus egertoni*, Forb., and *Lytoceras* (*Gaudryceras*) *kayeii*, Forb., from which two species known in the upper senonian, *Pachydiscus neubergicus*, Hauer, and *Lytoceras planorbiforme*, Böhm, can scarcely be distinguished. As to the other species, their European representatives are, as the list shows, restricted solely to the upper senonian and belong partly even to the typical forms, as, for example, *Baculites anceps*, corresponding to *Baculites vagina*; *Hamites cylindraceus* DeFr., which represents the Indian *Hamites rugatus*, Forb.; and *Scaphites constrictus*, Sow., to the relationship of which *Scaphites cunliffei*, Forb. belongs. Of great importance for the determination of the age of the beds are also the following species, viz., *Sphenodiscus siva*, Forb. (cf. *S. udaghysi*, Gross.), *Amm. (n. g.) brahma*, Forb. (cf. *A. haugi*, Seunes), *Puzosia remba*, Forb. (cf. *P. fayoli*, Gross.) *Pseudophyllites indra*, Forb. (cf., *Ps. colloti*, Gross.), *Pachydiscus erishna*, Forb. (from the Group of *P. egertoni*, or *neubergicus*), etc. (see the general list).

Among the genera and subgenera in the ammonite fauna of the Valudayur beds (*Phylloceras*, *Gaudryceras*, *Tetragonites*³ *Pseudophyllites*, *Anisoceras*, *Ptychoceras*, *Baculites*, *Sphenodiscus*, *Holcodiscus*, *Pachydiscus*, *Hauericeras*, *Desmoceras* *Scaphites*) not one—with the possible exception of *Ptychoceras*—is foreign to the European senonian, a circumstance which sufficiently proves, that the

¹ H. F. Blanford, Cret. of S. Arcot and Trichinopoly Districts: Mem. Geol. Surv., India, IV, Chap. VIII.

² F. Stoliczka, in H. B. Medlicott's Geological Sketch of the Shillong Plateau in N.-E. Bengal: Mem. Geol. Surv., Ind., VII, pt. i, p. 182, ff.

³ M. A. de Grossouvre communicated to me that he had met with a species related to *Tetragonites cala*, Forb., in the French senonian.

apparent anomalies in the cretaceous fauna of Southern India has been dissipated since the corresponding European deposits have become better known.

The ammonite fauna of the Trigonoarca beds, consisting of four forms, shows the same relations as the fauna of the Valudayur beds; it has three species in common with the latter, the fourth, *Pachydiscus gollevillensis*, Orb., is a form recognized as occurring with *Pachydiscus neubergicus* in Europe.

Of much less importance for the determination of the age of the beds are the other animal groups, which, however, completely confirm the results attained by the aid of the ammonite fauna. They have likewise undoubted relationship with the European senonian. (For example, *Exogyra ostracina*, Lam., *Alectryonia ungulata*, Schloth., *Pholadomya lucerna*, Forb. (cf. *caudata*, Röm.), *Modiola flagellifera*, Forb. (cf. *flagellifera*, Zittel), etc.)

As to the Nerinea beds there is much less material at hand for the determination of their age; but their stratigraphical position, the complete want of ammonites, and the presence of *Nautilus danicus* permit of their being correlated, with great probability, with the European danian.

According to these results the Pondicherri beds may be regarded as the uppermost stages of the cretaceous system: the Valudayur and the Trigonoarca beds are equivalent to the upper senonian (campanian, mucronata beds), the Nerinea beds to the zone of *Nautilus danicus* (danian).

We obtain a confirmation of these conclusions in the investigation of the fauna of the Trichinopoli district, in which the whole of the upper cretaceous is developed. There also the cephalopod fauna of the Ariyalūr stage, so far as it can be compared with the European, shows a decided upper senonian character (*Pachydiscus olacodensis*, Stol. (cf. *colligatus*, Binkhorst), *P. egertonianus*, Forb. (cf. *neubergicus*, Hauer), *Baculites vagina*, Forb., var. *simplex*, Koss. (cf. *anceps*, Lam.) while in the upper part of the underlying Trichinopoli stage occur characteristic lower senonian species (for example, *Schloenbachia* (*Peroniceras*) *dravidica*, Koss. (cf. *iricarinata*, Orb.), *Placenticeras tamulicum*, Blanf. (cf. *syrtale*, Morton), and also the turonian and cenomanian (lower Trichinopoli and Utatūr stages) follow each other in the same order as in Europe. One is therefore justified in adopting the European divisions of the upper cretaceous for these deposits, and in going so far as to say that the Ariyalūr beds of the Trichinopoli and Pondicherri districts are not only to be considered as an approximate equivalent of the senonian (Stoliczka, Cret. S. India, Vol. IV, p. II.) but as representing a definite part of it, viz., the upper senonian.

Seunes¹ states regarding the distribution of the uppermost stage of the Senonian as follows:—"D'après l'analogie de la faune des *Ammonitidæ*, on est amené à regarder comme sensiblement synchronique des couches à *Pachydiscus jacquoti* des Pyrénées (Maëstrichtien); le Dordonien de l'Aquitaine; le Calcaire à *Baculites* du Cotentin; le Tuffeau de Maëstricht à *Ammonites* et à *Hemipneustes* (= partie supérieure des couches à *Belemnitella mucronata* de la Belgique), la partie supérieure des couches à *Belemnitella mucronata* d'Aix-la-Chapelle; la Craie de Limbourg; la craie de Lemberg (Galicie); la Craie à *Pachydiscus gollevillensis* d'Irlande; la partie supérieure des couches à *Ammonitidæ* du groupe

¹ Contributions à l'étude des céphalopodes: Mém. de la Soc. Géol. France, Paléontologie, Vol. II., 1891, p. 21.

de l'Arriyalur de l'Inde anglaise et de Pondichéry." I have quoted this passage verbatim, because in it the correlation of the peculiar ammonite faunas of the upper campanian, the latest ammonite fauna known up to the present time, is precisely given, and the position of the Ariyalur stage correctly indicated. But it may be pointed out with reference to the latter that not only the upper beds of the ammonite bearing Ariyalur stage of Ariyalur and Pondicherri, but also the lower beds, consequently the Valudayur beds, formerly considered as cenomanian, belong to this stage. Seunes rightly remarks further, that the similarity of the Indian and European deposits of this period is still more increased by the fact that they are in both regions immediately overlaid by the zone of *Nautilus danicus* in which ammonites are absent.

IV.—INDO-PACIFIC EQUIVALENTS OF THE ARIYALUR STAGE IN PONDICHERRI.

Putting aside the cretaceous deposits of Assam, which, according to our present knowledge, seem to be nearly identical with the Pondicherri deposits, but still require a more minute study, there are within the area of the Indo-Pacific ocean the following cretaceous regions, which may be brought into close relationship with the Ariyalur stage: Natal, Borneo, Yesso, Vancouver Island (and California), Quiriquina Island (Chili)

In Natal¹ the upper Trichinopoli and Ariyalur stages are represented by numerous fossils; to the latter the following species specially point: *Puzosia* (*Hauericeras*) *gardeni*, Baily, *P.* (*Hauericeras*) *rembda*, Forbes., *Lylocerus* (*Gaudryceras*) *kaye*, Forbes., *Anisoceras indicum*, Forbes., *Pugnellus uncatus*, Forbes., *Solariella radiatula*, Forbes., *Polia pondicherriensis*, Forb., *Turritella breantiana*, Orb., all forms which frequently occur in the Ariyalur stage of the Pondicherri and Trichinopoli districts.² From Madagascar, besides some *Ostreæ* of the senonian Ariyalur stage³ (for instance *Alectryonia unguolata*, Schl.), a *Turritites* nearly related to *T. tuberculatus*, Bosc., *Baculites baculoides*, Lam., and an *Acanthoceras* belonging to the group of *A. rotomagense*, were recently brought to Europe, all the latter indicating cenomanian⁴ species.

In Yesso, too, where, it is true, no division of the cretaceous was attempted, the Ariyalur stage certainly does not occur isolated, for besides numerous species which are characteristic of it (for example, *Puzosia gardeni*, Baily, *Pachydiscus ariyalurensis*, Stol., *Pach. sp. pl.*, *Anisoceras largesulcatum*, Forbes., etc.) there is also recognized a series of forms which are related to, or identical with, those of the Trichinopoli and Utatur stages.⁵

¹ C. L. Griesbach, Geology of Natal: Quart. Journ. Geol. Soc. London, XXVII, 1871, p. 60 ff.; W. H. Baily, Description of some Cretaceous fossils from Southern Africa: *ibid.*, XI, 1855, p. 454 ff.

² F. Kossmat: Die Bedeutung der südindischen Kreideformation: Jahrb. k. k. geol. Reichsanstalt, Wien, XLIV, 1894, Heft 3, p. 454-65.

³ R. B. Newton: Quart. Journ. Geol. Soc. London, XLV, 1889, p. 333.

⁴ M. Boule, Notes sur les fossiles rapportés de Madagascar, par M. E. Gautier: Bull. du Muséum d'histoire Naturelle. Paris, 1895. No. 5, p. 4.

⁵ Compare the works upon Yesso, by M. Yokoyama: Palæontographica, XXXVI, Stuttgart, 1890; and K. Jimbo: Palæontologische Abhandlungen, Bd. VI, Heft 3, Jena, 1894.

In Borneo¹ only the Ariyalūr stage (with *Nautilus trichinopolitensis*, *Terebratulula biplicata*, *Exogyra ostracina*, *Nerinea*, etc.) is known up till now, but an overlap of it cannot be recognized until the conditions there are better known.

The Ariyalūr overlap has been recently shown in the clearest manner by Steinmann in the Island of Quiriquina (Chili), which, as regards the occurrence of the cretaceous deposits, possesses a great resemblance to Vancouver Island. The cretaceous deposits of these two islands show a particularly interesting faunistic accordance with Pondicherri.

In southern Vancouver the Nanaimo stage immediately succeeds the folded palæozoic and crystalline rocks. This stage has typical senonian forms even in the lowest division (Division A and B, Richardson): for instance, *Puzosia gardeni*, Baily, *Pachydiscus newberryanus*, Meek, *Hamites obstrictus*, Jimbo. (aff. *rugatus*, Forbes.), *Baculites occidentalis*, Meek. A large number of the species pass up into the higher horizons, in which *Lytoceras indra*, Forbes., and *Lytoceras aff. kayei*, F. (= *jukesii*, Whiteaves²) are found; these are species quite characteristic of the Valudayur type. I had the opportunity at the British Museum in London of studying a collection of ammonite species from Vancouver which had not yet been worked out, and I found among them likewise only forms which pointed to a very high horizon of the upper chalk: *Lytoceras indra*, Forb., *Pachydiscus otacodensis* Stol., *Pach. newberryanus*, Meek, *Pachydiscus* sp. nov. aff. *tweenianus*, Stol., *Schloenbachia* sp. nov., *Hamites obstrictus*, Jimbo, *Heteroceras* aff. *cooperi*, Meek, *Baculites occidentalis*, Meek, etc. All the specimens are found in greyish black, tough, somewhat splintery concretions and are mostly beautifully preserved. The occurrence of the two species *Lytoceras indra* and *Pachydiscus otacodensis* in Vancouver is also of importance in connection with the Indian conditions, for it increases the similarity between the Ariyalūr stage of Otacod and the Valudayur beds of Pondicherri. The fauna of the Nanaimo stage of Vancouver and the adjacent Islands was recently greatly enriched by Whiteaves,³ and among others a Japanese species of *Pachydicus* (*Pach. haradai*, Jimbo) was recognized. I was enabled through the kindness of Mr. Whiteaves to study some very interesting new ammonites from the Straits of Georgia, which enhance the similarity between the Valudayur beds and the Nanaimo stage considerably, and I think myself justified in coming to the conclusion that the Nanaimo stage (=uppermost Chico beds of California) represents an equivalent of the Ariyalūr stage in the strict sense of the term.

In the Island of Quiriquina the cretaceous lies likewise in flat layers immediately upon the folded and denuded crystalline rocks below. These Quiriquina beds, as Steinmann calls them,⁴ consist chiefly of sandy rocks rich in glauconite, which contain numerous remains of saurians and marine molluscs, and are unconformably overlain by a coarse tertiary conglomerate. Among the molluscs are nine species of ammonites, four of which Steinmann has identified.

¹ K. Martin, Die Fauna der Kreideformation von Martapoera: Sammlungen des geologischen Reichsmuseums in Leiden, Bd. IV, 5, 6, 1889.

² J. F. Whiteaves Geol. and Nat. Hist. Surv. of Canada, Mesozoic Fossils, Vol. II. 1879.

³ F. Whiteaves, On some fossils from the Nanaimo group of the Vancouver cretaceous: Trans. Roy. Soc. Canada, 2nd series, I, Sect. iv, 1895, p. 119 ff.

⁴ G. Steinmann, Das Alter und die Fauna der Quiriquinaschichten in Chili: Neues Jahrbuch Beilageband X, Stuttgart 1895.

with known species of Valudayur beds, namely, *Phylloceras surya*, *Lytoceras kayei*, *L. varuna*, *Baculites vagina*. As far as one can judge from figures, the similarity is indeed very great, but I should like to draw attention to one circumstance of importance. In Pondicherri, as well as in Quiriquina, *Baculites vagina* is one of the most common fossils, but the varieties that are found in the two regions are not the same. The Chilian *Baculites vagina* is recognizable by the fact that the swellings of the ribs are a little nearer to the siphonal part of the shell than in the Indian type, for this reason the section appears to be more oval. This peculiarity may be constant, as I observed it also in the Chilian *Baculites* of this species in the British Museum, but I did not attach much value to it then as the specimens in question were not adults. Nevertheless the Chilian specimens deviate less from the typical form than the American *Baculites occidentalis*, Meek, and *B. chicoensis*, Gabb, which replace in Vancouver and California the *Baculites vagina*.

To the species which remind one of forms from Southern India belong also *Holcodiscus gemmatus*, Huppé, and *Pachydiscus quiriquinae*, Phill, of which the former is to be compared with *H. æmilianus*, Stol., the latter with *P. otacodensis*, Stol. Of the Chilian *Hamites*, cf. *cylindraceus* Dfr., mentioned in Steinmann's work, there are at the Geological Institute of the University of Vienna plaster casts which show a perfect similarity of sculpture with the Indian *Hamites rugatus*, Forb.; unfortunately the sutures are unknown. I am not, therefore, in a position to identify them. Also a species of gastropod, *Pugnellus uncatulus*, Forb., is common to this cretaceous horizon, to Southern India, and to South Africa. Relationship with the upper chalk of New Zealand (with *Plesiosauria*, *Baculites anceps*, McKay) is indicated, according to Steinmann, but it is still too incompletely examined to be discussed at present.

It is worth while to emphasize the fact that the character of the cretaceous deposits in Quiriquina in spite of their great distance from other known cretaceous regions, answers completely to what one might expect from their position in the Pacific region, and thus gives good proof of the unity of this great geographical province of animals.

V.—THE ZOOGEOGRAPHICAL CONDITIONS OF THE INDO-PACIFIC REGION.

The distribution of some species of the Indo-Pacific cretaceous province is extraordinarily wide and, owing to their close connections with the geographical conditions of that period, very interesting.

Even the most widely separated deposits of the Indo-Pacific province, namely, Natal, Vancouver, and Quiriquina show a striking resemblance to each other, and are connected not only by representative but also by some very distinctly identical species; I may mention *Lytoceras kayei* (Natal, Pondicherri, Vancouver (?), Quiriquina), *Lytoceras indra* (Natal,¹ Pondicherri, Vancouver), *Puzosia gardeni* (Natal, Ariyalūr, Vancouver). And yet the shortest line of connection between Pondicherri and Quiriquina amounts to about half the circumference of the globe and consequently the area of distribution of many forms must have been of vast extent and the most varied climatic conditions must have prevailed in it.

Pondicherri lies in about 13° N. Lat., 80° E. Long. from Greenwich; the central

¹ In a new collection at the British Museum which Mr. G. C. Crick showed to me.

European localities (with a similar cephalopod fauna) in about 40-50° N. Lat., on both sides of the meridian of Greenwich; Vancouver about 49° N. Lat., 125° W. Long. from Greenwich; Natal about 30° S. Lat., 32° E. Long. from Greenwich; Quiriquina Island about 36° S. Lat., 73° W. Long. from Greenwich. Thus two of these faunistically allied cretaceous areas belong to the north temperate zone, two to the south temperate zone, and one to the tropical zone; their position with reference to each other is such that they would fall into quite different geographical latitudes even if the poles occupied at that time positions different to their present ones.

Therefore the distribution of the ammonites depends not so much upon the climatic as upon the geographical conditions.

In a certain degree the study of the zoogeographical conditions of the modern oceans gives similar results as regards the wide distribution of Indo-Pacific species on the one hand, with the great faunistic differences between the east and west coasts of America on the other (Fischer : Manuel de Conchyliologie, Vol. I, p. 158).

It is true that at the present time the climatic differences seem to be much greater than in the cretaceous epoch, so that the distribution of species towards the north and south is in consequence rather more narrowly restricted, whilst in the senonian, for example, the Ariyalūr fauna can be well recognized not only in the tropics, but also in the two temperate zones.

But in this respect there is a great difference between the different animal groups; the ammonite fauna has generally a more universal, the gastropod and bivalve fauna a more local character, but this cannot be established as a rule without reservation. There are also among the latter classes of animals very widely distributed species (for example, *Exogyra ostracina*—Europe, India, Borneo; *Alectryonia unguolata*—Europe, Madagascar, India; *Vola quinquecostata*—Europe, Syria, Natal, India, Borneo, etc.; *Protocardium hillanum*, Sow.—Europe, Africa, India; *Pugnellus uncatulus*—Natal, India, Chili, etc.), but these are proportionally more rare than among the ammonites. Moreover in the latter it is not the species that have generally such an extremely wide distribution, but a certain, more or less defined, series of representative forms. Nowhere is this better shown than in the Valudayur beds, whose ammonite fauna is distinctly related to that of the upper senonian, and yet has only two species (*Pachydiscus egertoni* and *Lytoceras kayei*), with some probability, in common therewith. One can completely agree with E. Forbes's view (Fossil Invertebrata from Southern India, p. 169) "that the marine faunas of distant localities, under similar conditions of climate, depth and sea-bottom, maintain their relations rather by representation of forms by similar forms, than by identity of species." The distribution of the ammonites is subject to the same laws as that of all other marine invertebrates, with the difference that these animals, according to the special structure of their shells, were capable of a wider distribution through the ocean currents, etc., and partly also through free locomotion. The rule, applying also to the ammonites, that a group of representative forms (Formengruppe) has a much wider distribution than a single species belonging to it (for instance, the group of *Baculites anceps*, Lam., a wider one than *Baculites anceps* itself) proves that these animals during their distribution over the surface of the ocean were liable to specific variations, and it is thus impossible that

the transportation of the empty shells¹ of a group of ammonites inhabiting a limited area should be capable of explaining the universal distribution of the fossil remains belonging to it.

An interesting fact, which has been emphasized by Steinmann,² is, that some Pacific types appear in the European senonian, some more rarely (*Lytoceras*, *Phylloceras*, *Hamites*), some more frequently (*Pachydiscus* and *Baculites*), and he infers from this that at that period a migration of part of the Pacific fauna into the Atlantic ocean took place on a large scale. Such a migration appears in fact to have taken place, and the Indian cretaceous lying between the Atlantic and Pacific regions is well situated to prove an exchange of the faunas.

But the question whether certain ammonite types came from the Pacific into the Atlantic or from the Atlantic into the Pacific, is not always easy to decide. For instance, certain upper senonian *Pachydiscus* and *Baculites* forms occur in the European as well as in the Indo-Pacific areas in an abundance of rather similar forms and individuals, and the stratigraphical position which they occupy (between the beds with *Nautilus danicus* and the beds of the lower senonian with *Placentoceras* and *Schloenbachia tricarinata*), is completely analogous in both areas, so that their synchronism may be assumed. For this reason every method of discovering their habitat fails us. In many groups the probability is very strong that it is the Pacific ocean [for instance, in certain *Lytoceras* (*Gaudryceras*) forms, in many *Puzosia* types (*Hauericeras*), etc., whilst others originated, it is tolerably certain, in the Atlantic area (*Sphenodiscus*, *Scaphites*, *Turritiles*, etc.)]; but the question is still very difficult and can only be answered satisfactorily in special cases. Prof. Steinmann lays stress upon the fact, that the greater number of Pacific types in Europe are restricted to the western and north-western parts, whilst they are absent in the southern and eastern, and he is inclined to suppose that the immigration took place from the Pacific ocean across the Arctic seas north of Asia or America. I have tried³ to show that an exchange of faunas between the Atlantic and Pacific oceans took place in the seas south of the Indo-African continent, and that the immigration of Pacific types into Europe is clearly demonstrable in this manner. Supposing a circumpolar exchange of faunas, the most northerly deposits of upper cretaceous in the Pacific ocean ought to contain the greatest percentage of European forms; but this is not the case. The fauna of Vancouver is of purely Pacific type, as is that of Quiriquina, without any European intruders being recognizable in it, whilst such are still of great importance in the fauna of the cretaceous of Southern India, which agrees with the view that I have expressed. It becomes more and more evident that the Atlantic types decrease with tolerable constancy from west to east in the Indo-Pacific province. This is especially the case in the cenomanian and lower senonian. The series of forms of *Schloenbachia inflata*, Sow., has its habitat in the Atlantic ocean (Central Europe, West Africa, Brazil), and is distinguished there by a great abundance of species and individuals; it occurs also in India, where it is likewise well represented, and sends forth into the Pacific only quite isolated, rare forms. Similarly the group of *Acanthoceras rotomagense*, DeFr., which has its chief

¹ J. Walther: *Bionomie des Meeres*. Jena, 1893. Bd. II., p. 508 ff.

² G. Steinmann: *Das Alter und die Fauna der Quiriquina Schichten*, p. 30.

³ F. Kosmat: *Die Bedeutung der Südindischen Kreideformation*, p. 466.

distribution in the Atlantic ocean (Europe, Brazil), was recently discovered in Madagascar, along with other typical Atlantic cenomanian forms (*Turrilites*, *Baculites baculoides*), is extremely abundant in India, together with *Turrilites* and *Hamites*, but is extremely rare in the cenomanian of the true Pacific province (Yesso, California), whilst *Turrilites* are there entirely absent. We therefore find the greatest similarity with Atlantic cretaceous deposits not in the northern part of the Pacific, in the vicinity of the Polar sea, but decidedly in its western part, the Indian ocean. Species of *Schloenbachia* of the group of *Schloenbachia tricarinata*, *Placenticeras* of the group of *Pl. syrtale*, which, during the period of the lower senonian, attained such a great development in the northern part of the Atlantic ocean, on the American as well as on the European side (deposits of this age are unknown in the southern Atlantic area), came into the Indian seas (*Schloenbachia soutoni*, and *Schl. stangeri* in Natal, *Schl. dravidica* and *Placenticeras tamulicum* in Trichinopoli), but then disappear. In the Pacific ocean there is known only a quite isolated *Schloenbachia* of this group in California, and a very aberrant *Placenticeras* in Yesso. Similar conditions also obtain in the upper senonian. Whilst the similarity to corresponding deposits in Europe is not great, and recognizable Atlantic types are wanting in the fauna of Vancouver, Yesso and Quiriquina, we find in the Valudayur beds of Southern India rather a large number of species which are nearly related to European ones. We meet with, for example, *Sphenodiscus*, a genus which is elsewhere only known in the area of the Atlantic and Mediterranean cretaceous (North America, Europe, North Africa, Baluchistán), two *Scaphites* related to *Sc. constrictus*, Sow. (not yet known in the typical Pacific senonian), etc. That in this way not only did Atlantic species migrate into the Pacific region, but also Pacific species into the Atlantic, is shown by the occurrence of typical Pacific forms (*Puzosia remba*, Forb., *Lytoceras kayei*, Forb., *Lyt. indra*, Forb.) in Natal; and these are just the very species whose related forms belong to the most important Pacific types in Europe (*Puzosia fayoli*, Gross., *Lytoceras planorbiforme*, Bohm., *L. colloti*, Gross.)

Whilst on the one hand the Indian fauna contains a mixture, of Pacific and Atlantic elements, and whilst the former increase in the cretaceous areas lying to the eastward, the latter do so to the westward (Madagascar, Natal, West Africa, etc.), and an exchange of faunas in the way pointed out, that is, round the Indo-African continent, can certainly be proved, there is as yet no solid ground for the belief that a circumpolar exchange of the faunas was effected.

The occurrence of *Baculites* on the Sosswa, east of the Ural (62°5' N. Lat.), mentioned by Professor Steinmann, may only indicate that the Central European cretaceous overlap, which extended far into Russia, penetrated to this latitude; for *Baculites* is very common throughout the upper cretaceous of Europe. But the discoveries in Greenland¹ (Niacornat, Ata, Patoot) show in their fauna very near relationship to the Fort-Pierre and Fox Hills Group of the United States and thus seem to oppose the idea of a migration of Pacific forms through the Polar seas. Nevertheless the possibility is not excluded that further research in the Polar regions may furnish evidence that there also during cretaceous times the sea flowed,

¹ P. de Lorient, Om fossile Saltvandsdyr fra Nord-Grønland: Meddelelser om Grønland. Vol. V. Kjöbenhavn. 1883, Part IV.

and thereby the northern parts of the Atlantic and Pacific oceans were connected together. But it may be asserted with confidence that an exchange of the faunas between the two great oceans can only be proved at the present time with perfect certainty by the deposits of Natal and Southern India, and that the phenomena recognized there are sufficient to explain the occurrence of Pacific types in Europe. Moreover it becomes more and more clear that the European faunas of the upper senonian, which are related to those of the Pacific ocean, are not only restricted to the northern and north-western parts of Europe but are also found in central and southern Europe, especially in the vicinity of the Atlantic ocean. The beds of *Pachydiscus neubergicus* are known, for instance, from the northern slopes of the Pyrenees (Stegaster limestone of Gan, with numerous ammonites, including also Pacific types), from the south side of the Pyrenees and even from N. Africa (Tunis).

This brings us to quite a peculiar and unexpected phenomenon. In the same regions of the Pyrenees, in which senonian ammonites are found, whose related forms recur in middle Europe and southern India, rich echinoderm faunas are known, which also, like the rest of the fauna, are for the greater part typically Mediterranean. This is only to be explained, I believe, by the circumstance that some ammonite types, by virtue of their great powers of distribution, penetrated from the open ocean into the otherwise faunistically very isolated Mediterranean region.

Noetling's palæontological researches¹ have proved that the echinoderm fauna of the Dunghán stage (Sphenodiscus beds) of Baluchistán is very closely related to that of the Danian of the Pyrenees, and even possesses some species in common with it, whilst it is quite different from the fauna of the Ariyalúr stage of Southern India.

This result would be quite in conformity with the fact that the echinoderm fauna of the Bágh beds (Narbada region) is in close connection with the cenomanian of the Mediterranean area of S. Europe, North Africa and Syria, but is quite different from that of the Utatúr beds which are, however, of the same age;² the conclusion come to with reference to the geographical distribution of land and sea is in both cases therefore the same, namely, that a Mediterranean sea stretched from Southern Europe eastward far into Asia, without being connected with the Indian Ocean.³ Unfortunately the proofs deducible from the echinoderm fauna of Baluchistán are considerably weakened by the fact that in Southern India the echinoderms occur in the upper senonian Ariyalúr beds, whilst in the overlying faunistically very sharply separated Niniyur beds (danian) they are up to the present time wanting; it is therefore to be expected that on account of the difference in age the echinoderm fauna of the danian of Baluchistán must be different from that of the upper senonian Ariyalúr stage. It is true that the dissimilarity of the faunas seems to extend to the other animal groups, as Dr. Noetling wrote me on one occasion that the cretaceous of Baluchistán has only a few cosmopolitan species in common with that of Southern India. An early publication of the researches referring to this subject, especially on the *Ammonitidæ* (which appear not to be rare

¹ F. Noetling, Preliminary notice on the Echinoids from the upper Cretaceous system of Baluchistán: *Rec. Geol. Surv. Ind.*, XXVII, 1894, p. 129.

² P. M. Duncan, On the Echinoides of the Cretaceous Strata of the Lower Narbada Region: *Quart. Journ. Geol. Soc. London*, XLIII, 1887, p. 154.

³ W. T. Blanford: *Rec. Geol. Surv. Ind.*, XXIX., 1896, p. 53, 54.

and might indicate the existence of a lower horizon than the danian), would be very desirable. It is to be regretted that the echinoderms only of the Narbada cretaceous have been reliably worked up, whilst the rest of the fauna is known only incidentally. It depends in the first place on the exact investigation of these two cretaceous areas whether the view that the south Indian ocean was entirely excluded from the Mediterranean during the time of the upper chalk can be definitely affirmed. What is known up to the present time about the Asiatic upper cretaceous is decidedly in favour of this view.¹

VI.—THE CORRELATION OF WIDELY SEPARATED FOSSIL-BEARING DEPOSITS.

The distance of the Indo-Pacific cretaceous deposits from those of Europe with which they are compared for the purpose of determining their age is so great that the doubt is justifiable whether the similarity of the faunas allows us to establish an approximately correct comparison between them as regards the time of their deposition. Professor Steinmann leaves it an open question whether the Ariyalūr overlap occurred during the period of the lower senonian (the time of the overlap of the Gosau formation and the Aachen deposits), or, as the fauna would indicate, during the upper senonian (loc. cit., p. 31). I think that in this case the question can be decided with tolerable certainty on the evidence of the fauna. I have already mentioned that two species of the groups of *Schloenbachia subtricarinata*, d'Orb., and of *Placenticeras syrtale*, Mort., which are peculiar to the Atlantic lower senonian, and everywhere very common in it, occur in the upper Trichinopoli stage. It is therefore impossible that the upper Trichinopoli stage could be older than this division, as the two ammonite types referred to must have immigrated from there, and from this it results that the Ariyalūr overlap which begins above the horizon of these ammonites, must be younger than the lower senonian, therefore younger than the Aachen overlap.

The overlap of the lower senonian appears, according to present knowledge, to be confined to the Atlantic region, and indeed is not only found in Europe but also in the East-coast States of North America (from New Jersey to Alabama). There follows everywhere, immediately above the plant-bearing non-marine cenomanian a marine formation, which contains quite a typical lower senonian fauna: *Schloenbachia* of the group of *Schl. (Mortonicerias) teæana* Röm., *Placenticeras syrtale*, Morton, *Pl. placenta*, DeKay, *Baculites asper*, Morton, etc.,

¹ It is known that Neumayr (Gograph. Verbreitung der Juraformation) came to the conclusion that during the jurassic and the lower cretaceous India was connected by a land barrier with South Africa. But he was obliged on account of the jurassic discoveries in Mombassa and Madagascar, whose relations with India are unmistakable, to transfer this land connection to the extreme south, and through some recent observations it has become doubtful whether such a connection existed at all. Pavlow has shown that an *Olcostephanus* from Uitenhage beds, studied by him was scarcely to be distinguished from *Olcostephanus schenki*, Oppel, from the Spiti shales (Pavlow and Lamplugh; Argiles de Speeton et leurs equivalents. Bull. Soc. Imp. Nat. Moscou. 1892, p. 493) an observation which I am inclined to confirm from a comparison of an African specimen contained in the Geological Institute of the University of Vienna with Oppel's figures. Moreover, the relations of some Uitenhage fossils to the lower neocomian of the Salt Range, which will be worked up by Professor Waagen and myself, are very striking, and cannot easily be explained otherwise than by a oceanic connection, which probably separated India and Africa and connected the Mediterranean Sea of the lower cretaceous period with the Indian Ocean.

and is evidently equivalent to the Fort Pierre group of Dakota, whilst only in the higher beds does *Sphenodiscus lenticularis*, Owen, a typical form of the upper senonian Fox Hills group, occur.

The overlap of the European lower senonian is therefore by no means of merely local significance, though it is not observed in the Pacific ocean.

There is moreover in Europe besides the lower senonian overlap also a local overlap of the upper senonian, which, however, does not appear to be of great extent, but by reason of the faunistic relationship to the Pondicherri cretaceous is of great interest: namely, that of the Baculite chalk of Cotentin, France, which reposes immediately upon much older rocks, and as already mentioned (p. 70) possesses much similarity in its ammonite fauna to the Valudayur beds. The interest is increased through Zittel's¹ observations in the Lybian desert, where the zone of *Exogyra overwegi*, Buch., which lies immediately upon the plant-bearing Nubian sandstone, is placed in the upper senonian, on account of the general aspect of its fauna and of some identical species, and is paralleled with the so-called lower danian (Baculite-limestone of Cotentin). Moreover another overlap has been recently pointed out in Asia and its age more nearly determined, namely, that of the *Cardita beaumonti* beds of Baluchistán which lie immediately upon the neocomian. Their echinoderm fauna possesses, according to Noetling, a purely Mediterranean character, entirely different from that of the cretaceous of Southern India, and has many important and remarkable species in common with the danian of the Pyrenees (horizon above the *Stegaster* limestones). Ammonites occur there likewise (*Sphenodiscus*, further also, according to Oldham, *Baculites*, *Crioceras*?), and it is therefore very probable that the overlap of the *Cardita beaumonti* beds, which is also noticeable in the Salt Range, was not very widely separated in time from the Ariyalūr overlap.

It is a truly remarkable phenomenon that the period of the upper cretaceous begins with the great overlap of the cenomanian, but that also during the lower senonian, as well as the upper senonian and the danian, the sea overflowed the land very extensively in various parts of the earth's surface. The cause of this is of course for the present as inexplicable as is the negative change of relative level, which characterizes the beginning of the tertiary era in so many places throughout the world.

The overlaps are moreover, it would seem, an excellent check upon the correctness of the calculations of the age of many deposits, and this is especially the case with reference to the cenomanian and upper senonian. The cenomanian overlap begins in Europe and in Southern India with the same zone (*Schloenbachia inflata*, Sow., *Stoliczkaia dispar*, d' Orb., *Hamites armatus*, Sow., etc.), perhaps also in West Africa (Elobi Islands and Angola) and in Brazil. As on the other hand in the Mediterranean province, where also in many places the overlapping of the cenomanian can be proved (Syria, Arabia, Narbada, etc.,) the fauna is composed chiefly of other elements, there is no doubt that overlap and the occurrence of a special fauna are in no causal connection with one another, but are quite independent phenomena. Supposing this to be the case the coincidence in time of the overlap with the appearance of a similar fauna

¹ K. A. von Zittel: Beiträge zur Geologie und Paläontologie der libyschen Wüste Paläontographica, XXX, 1883, pp. 89, 93.

in a series of widely separated places in the Atlantic and the Indian oceans must be a proof of the actual synchronism of these deposits.

Also in the upper senonian the coincidence of the beginning of the overlap with the appearance of the Ariyalūr fauna in Southern India, Vancouver, and Quiriquina speaks quite decidedly for the synchronism of these deposits. That in Southern India the fauna of the overlapping Ariyalūr stage resembles so closely the fauna of the overlapping upper campanian of Cotentin permits the conclusion that these phenomena, too, are synchronous, and thus the succession of the overlaps might afford a very reliable guarantee of the correctness of the determination arrived at as to their age founded upon the fauna.

There is, however, another means of proving in some cases whether widely separated, faunistically equivalent deposits may be called merely homotaxial or truly synchronous. An example may explain this. Suppose that a place in the Atlantic province (A) has a fauna consisting of the native species $a_1, a_2, a_3, \dots$ with which the Pacific species p_2 may be associated; a place in the Pacific Ocean P, on the other hand contain, besides the native fauna consisting of the species $p_1, p_2, p_3, \dots$ the migrated species a_3 ; thus the two species a_3 and p_2 would be common to both regions. If the migration occupied a geologically measurable time, it follows that if in the region A the forms a_3 and p_2 lie in the same zone, p_2 must have emigrated from a somewhat lower bed of the province P, whilst the species a_3 , on account of the time necessary for the migration from A to P, can only appear in the latter place in a somewhat higher horizon, that is: the two elements of the fauna originating in different regions can only be associated in one of the two regions, in the other they must be separated. But if this is not the case, we must conclude that the lapse of time necessary for the migration must have been short, compared with the duration of a palæontological zone. The rule is simple enough; but the collection of the material necessary for proof in a special case is very difficult. Almost only such regions as lie in two widely separated, faunistically independent ocean regions, connected together by a few species, can be suitable as a starting point. Within one and the same ocean province, however large it may be, the more circumscribed habitat of certain groups of species can scarcely be determined. A comparison of the Indo-Pacific with the Atlantic cretaceous appears to me to afford some data which permit us to approach this question, but I should like to point out that in such a difficult subject where the determination of the habitat of certain animal groups forms the starting point of the conclusions to be arrived at, one must go to work with the greatest caution, and in the present state of knowledge one must be satisfied with conclusions based on probability.

Two new peculiar ammonite types begin to appear in the Valudayur beds: *Pseudophyllites indra*, Forb., and *Amm. brahma*, Forb., both of typically Pacific character. The same series of forms are also represented in the upper campanian of Europe by some rare specimens (*Pseudophyllites colloti*, Grossouvre, *Ammonites haugi*, Seunes); in the same beds appear also *Gaudryceras planorbiforme*, Böhm, doubtless a Pacific species, which I cannot distinguish from *Gaudryceras kayei*, Forb. But on the other hand the decidedly Atlantic forms *Scaphites (constrictus)*, Sow., and *Sphenodiscus (ubaghsi)*, Gross., occur in the same

¹ Noetling: Records Geol. Surv. India, 1894. XXVII, p. 124 et seq.

horizon in Europe; the origin of the group of *Pachydiscus neubergicus*, Hauer, is not certain, but I should be inclined to consider it in the first place as a peculiar European group, as it seems not to be represented in the Pacific deposits of Vancouver and Quiriquina. But of the groups mentioned *Sphenodiscus siva*, *Scaphites cunliffei*, and *Pachydiscus egertoni*, Forbes (scarcely distinguishable from *P. neubergicus* Hauer), are met with in the Valudayur beds. In the Trigonoarca beds *Pachydiscus gollevillensis*, Orb., a form of the group of *P. neubergicus* which is of European origin, occurs, together with the Pacific type *Pseudophyllites*, also appearing in the same horizon in Europe. It is also of importance that the bivalves originating from the Atlantic region (*Gryphæa vesicularis*, Lam., *Exogyra ostracina*, Lam., *Alectryonia unguolata*, Schloth., *Inoceramus cripsi*, Mant.) which in their habitat everywhere characterize the upper senonian, penetrate also into the Ariyalûr group of the Indian ocean. Thus there are elements of Atlantic and Pacific faunas associated with each other, in the upper senonian of Europe and in the Valudayur and Ariyalûr beds of Southern India, and their distribution on both sides must have occupied much less time than the duration of this stratigraphical division required.

In the upper Trichinopoli beds of Varagur (Trichinopoli) *Placenticeras tamulicum*, Blanf., belonging to the Atlantic series of forms of *Plac. syrtale*, Mort., and the certainly Pacific *Gaudryceras varagurense*, Kossm., appear associated together. In a similar way *Gaudryceras mite*, Hauer (not easily distinguishable from *G. varagurense*), and *Plac. syrtale*, are connected together in the santonian of Europe.

Unfortunately we have, owing to the great distances, in the majority of cases, to deal not with identical but allied species, which must therefore be treated with great caution; in some cases, however, well defined groups of forms are in question which have only a certain small vertical distribution and therefore admit of tolerably certain conclusions about them.

An exact stratigraphy of exotic deposits, as well as a thorough investigation of their fauna might certainly supply much material for interesting observations. For the present, however, it may be sufficient to say that the phenomena accompanying the overlap, as also the study of the place of origin of certain series of forms and species, lead to the same results, namely, that the geographical distribution of a fauna does not necessitate any geologically measurable time, and that on the ground of the palæontological characters (in the first place of the ammonite faunas), one can obtain even in widely separated deposits a relatively exact determination of their age.

CONCLUSIONS.

1. The Deposits of Pondicherri fall into three palæontologically separate divisions: (1) Valudayur beds (Anisoceras beds), (2) Trigonoarca beds, (3) Nerinea beds.

2. The Valudayur and Trigonoarca beds together correspond with the lower fossiliferous Ariyalûr group of Blandford (Ariyalûr group proper); the Nerinea beds show on the one hand a similarity to this division, on the other to the uppermost beds of the Ariyalûr stage (Niniyur beds) and are probably an equivalent of the unfossiliferous sands which separate the two fossiliferous groups of beds in the Trichinopoli district.

The middle and lower divisions of the S. Indian cretaceous (Trichinopoli and Utatur stages) are not represented in the Pondicherri area.

3. The fauna of the Valudayur and Trigonoarca beds (= Ariyalūr stage, proper) corresponds with the uppermost beds of the European senonian (upper campanian Baculite-limestone of Cotentin), whilst the Nerinea beds are to be paralleled with the danian.

4. Equivalents of the Ariyalūr stage are known in Natal, Madagascar, Assam, Borneo, Yesso, Vancouver, and Quiriquina island (Chili). In the two latter places an overlap has been proved to have occurred upon much older rocks.

5. An influx of elements of the Pacific fauna into the Atlantic area during the upper cretaceous, and especially during the upper senonian, is to be recognized; it is proved that such an exchange of faunas in the seas took place south of the Indo-African continent.

6. The study of the geographical centres of distribution of certain series of forms, as well as the coincidence of the appearance of distinct faunas with overlaps, furnish in the present case the proof that the distribution of the species did not require any geologically measurable time.

PART II. DESCRIPTION OF SPECIES.

As the list of fossils shows, the Pondicherri collection examined by me comprises only very few new species, and I can therefore, in connection with the descriptions of most specimens, refer to the monographs of E. Forbes, A. d'Orbigny and F. Stoliczka. As to the ammonites, most of them, namely, the forms belonging to the genera *Phylloceras*, *Lyloceras*, *Anisoceras*, *Ptychoceras*, *Baculites*, and *Sphenodiscus*, were revised and in part newly figured in the first part of my investigations on the cretaceous of Southern India; I can therefore restrict myself here to remarks upon the most important species of other genera (especially *Pachydiscus*). The fossil wood which in some places is abundant in the cretaceous of Pondicherri (especially horizons A and E of Warth), and in the overlying tertiary Cuddalore sandstones, is to be examined by Dr. F. R. Krasser, and the results obtained will be published later on.

PACHYDISCUS GOLLEVILLENSIS, Orb. (Pl. VI. Fig. 1, a, b, c.).

- 1842. *Ammonites Lewesiensis*, d'Orbigny (in part), Terrains Crétacés, Vol. I, Pl. CI. p. 336.
- 1850. *Ammonites Gollevillensis*, d'Orbigny, Prodrôme de Paléont., Vol. II, p. 212.
- 1854. *Ammonites Gollevillensis*, Sharpe, Mollusca of the Chalk, Pl. XVII, Fig. 2, p. 48.
- 1891. *Pachydiscus Gollevillensis*, Seunes, Ammonites du calcaire à Baculites du Cotentin : Mém. Soc. Géol. France, Paléontologie, Vol. II, 1891, No. 2, Pl. V., Figs., 1-3, p. 10.
- 1893. *Pachydiscus Gollevillensis*, Grossouvre, Ammonites de la Craie supérieure, Mém. Carte Géol. de la France, Pl. XXIX, Fig. 4, Pl. XXXI. Fig. 9, p. 214.

The only example of *Pachydiscus* which has been found up to the present in the Trigonoarca beds shows the following characters:—The whorls have a high mouth, a rather narrow periphery, rounded at the edges, almost imperceptibly flattened in the median line, and high, very slightly curved sides, which flow inwards to form a low but distinct steep umbilical wall. The involution amounts to more than half of the preceding whorl, but its exact measurement

cannot be given as the inner whorls of the shell are evidently somewhat crushed. At the edge of the umbilical wall there are 9 to 10 tubercles from each of which proceeds an obscure radial rib, which disappears on the sides, so that its connection with the short, strong ribs on the periphery cannot be perceived. The outer ribs, of which I counted 24 on the last half of the outer whorl (all composed of air chambers), are very decidedly weakened in the narrow siphonal region, but somewhat thickened on either side; they only reach the outer part of the sides, and here they soon fade off. The suture-line is somewhat abraded, but is nevertheless very characteristic. The external lobe is much shorter than the first lateral lobe, the external saddle symmetrically twofold, and its base on each side much narrowed by deep cut indentations. From the deep, distinctly threefold, first lateral lobe arises perceptibly the basal limitation, as the second lateral and the first auxiliary lobe are becoming shorter than the preceding one. The first lateral saddle is about the same height as the external saddle and likewise twofold, the second lateral saddle is much smaller and not symmetrically shaped, the first auxiliary saddle is again somewhat larger and wider and is divided into two parts by an indentation which cuts just into the umbilical margin; to this indentation a few small ones are attached, which rapidly incline towards the suture, thus forming a small sutural lobe.

In all the characters above mentioned the Indian specimen agrees perfectly with the examples of *Pachydiscus gollevillensis* from the Baculite limestone of Cotentin (Dep. Manche), which are beautifully figured by Seunes and Grossouvre; the example figured by Seunes, Pl. V, fig. 2, shows an especially striking resemblance. The number of the short peripheral ribs, thickened on both sides of the siphonal line (25 in an arc equal to the last half whorl of the example here described) is almost exactly the same, likewise the number and shape of the umbilical tubercles, which in the French examples also fade away without any visible connection with the outer ribs. As to the suture line, a glance at Pl. XXX, fig. 2, in Grossouvre's monograph (the photographic reproduction of a cast with well preserved septa) shows that not the least deviation exists. In the French specimens also the lobes lean towards the umbilical suture; the first auxiliary saddle is divided near the margin of the umbilicus by an indentation, the little suspensory lobe is distinctly visible; the external lobe is smaller than the first lateral lobe.

One can therefore, without any hesitation, ascribe the example described from the Trigonarca beds to this characteristic species of the upper campanian (upper mucronata beds, Maëstrichtien).

It is further closely connected with *Pachydiscus crishna*, Forb., and *P. egertoni*, Forb., from the Valudayur beds. The latter has in common with it a section indicating a high mouth, short, strong ribs on the periphery (likewise somewhat thickened on each side of the siphonal line), and isolated umbilical tubercles; the suture line also is very similar. The difference is only shown by the fact that *Pach. crishna* increases more slowly, is less involute, and consequently possesses, a more open umbilicus.

Pachydiscus egertoni is distinguished from the two above mentioned forms by a wider, less high section, and therefore a more contracted suture line. Otherwise *Pach. egertoni* shows nearly in every respect the same characters as the European *Pach. neubergicus*, Hauer, a typical form of the upper campanian, and I should be embarrassed if I had to indicate marked differences between the two species.

I intend to reserve a minute investigation into the relationship of these species for the second part of my monograph on the ammonites of the South Indian cretaceous, and hope that meanwhile I shall have an opportunity of comparing Forbes's examples of *Pachydiscus egertoni* with those of the European species *P. neubergicus*.

The little species *Pachydiscus ganesa*, Forbes, = *P. soma*, Forbes. (see Pl. VI, fig. 2 a-c) is also very closely related to *P. egertoni*, and it is quite possible that it represents only an immature form of the latter. The young stage of growth of *P. neubergicus* possesses also quite an extraordinary resemblance with *P. ganesa*, as a comparison of the figured specimen in this work with Pl. XXVI, Fig. 3, in Grossouvre's Monograph shows.

It can now be affirmed with certainty that the four Indian species: *Pachydiscus egertoni*, *P. ganesa*, *P. crishna*, *P. gollevillensis*, represent a perfect equivalent of the European group of forms of *Pachydiscus neubergicus*, and have at least one species (*P. gollevillensis*) in common with it.

The fifth Indian species of *Pachydiscus*, *P. menu*, Forbes, belongs to quite another group of forms and is in the middle stage of growth exceedingly like *P. ariyalurensis*, Stol., but acquires a very peculiar second row of tubercles on the body chamber. It seems to me of importance that there is an undescribed species associated with *Pachydiscus neubergicus*, from Neuberg (Steiermark), which shows quite similar features of form and sculpture to those of *P. menu*. (The only specimen known to me is in the Geological Institute of the University of Vienna.)

Stoliczka has also described and figured (Pl. LII, Fig. 3), *Pach. menu*, from the Trichinopoli group of Anapadi, but an examination of the example mentioned proved that this identification could not be sustained.

Locality, $\frac{1}{4}$ mile west of Rautankupam, Trigonarca beds.

PACHYDISCUS sp. cf. *GOLLEVILLENSIS*, Orb. Pl. VI, Fig. 3, a, b, c.

Among the few species of ammonites which the Valudayur beds, once so rich in this group of animals, have furnished to this new collection, is a fragment, which must be referred to the genus *Pachydiscus*, but in consequence of its small size does not admit of all the characters necessary for the recognition of a species of this group, so rich in forms, being ascertained. The whorls increase very slowly and the involution amounts to about three fifths of their height. At a diameter of about 5 cm. the section is almost perfectly circular, a little wider than high; afterwards the sides become flattened and gradually merge into the rather narrow, rounded periphery, whilst their boundary at the umbilical wall is somewhat more distinctly marked. At the edge of the umbilicus there are rounded tubercles (on the figured fragment three in number), whilst elsewhere no trace of sculpture is to be seen.

The suture line agrees with that of *Pachydiscus neubergicus*, Hauer, and *P. gollevillensis*, shows exactly the same details of indentation, of the proportions in size of the individual lobes and saddles, as well as the inclination of the lobes towards the umbilical suture. The first auxiliary saddle is on the umbilical edge as in *P. gollevillensis*. On the whole the specimen described is pretty near to this species and is only distinguished from it by the want of ribs and by the slower growth. But as the young forms of the *Pachydiscus* belonging to this group are

smooth (for example, in *Pachydiscus neubergicus*), and the mode of growth of *P. gollevillensis* in its young stage is not known, one cannot decide without further information whether the present specimen belongs to a distinct species or not.

Locality, $\frac{1}{2}$ mile north of Tutipet, Valudayur beds.

DESMOCERAS DIPHYLLOIDE, Forbes, sp.

1846. *Amm. diphyloides*, Forbes, Trans. Geol. Soc., London, 2nd Ser., Vol. VII, p. 105, Pl. VIII, fig. 8.

1865. *Amm. diphyloides*, Stoliczka, Cret. S. Ind., Vol. I, p. 119.

Of this species there are in the collection of the Geological Society several very well preserved examples showing deep, S shaped constrictions, which Forbes does not mention in his description. I have before me in the new collection only a fragment of a large-chambered example (diameter about 7 cm.), which agrees very well with the specimens of the original collection, and which I shall figure later on in connection with them.

The section is somewhat higher than wide, the sides flattened merging gradually into the rounded periphery on the one hand, and into the umbilical wall on the other. The constrictions marking the cast are curved in an S-shaped manner, and project tongue-like on the periphery.

The suture line shows all the characters of a *Desmoceras* of the group of *D. latidorsatum*, Mich.

The examples which Stoliczka figures from the Utatur group as *Amm. diphyloides* show a somewhat more rounded section (Pl. LIX, Figs. 10, 12); the constrictions show a shorter, broader tongue on the periphery. From the Ariyalūr stage of Otacod and Karapadi there are some specimens, which agree well in form, sculpture and suture line with the Valudayur form. Very nearly related also is *Desmoceras pyrenaicum*, Gross.¹ from the French santonian (middle senonian) and *Amm. selwynianus*, Whiteaves,² from the Nanaimo stage of Vancouver, of which Mr. Whiteaves sent me a very beautiful example for comparison.

The second species of *Desmoceras* from the Valudayur beds, *D. yama*, Forbes, is insufficient for any comparison with forms from other cretaceous regions.

Locality, $\frac{1}{2}$ mile north-west of Rautankupam, Valudayur beds.

AMM. (n. g. aff. HOLCODISCUS) BRAHMA, Forbes.

1846. *Amm. brahma*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, p. 100, pl. VIII. Fig. 1.

1865. *Amm. brahma*, Stoliczka, Cret. S. India, Vol. I, p. 163, Pl. LXXIX, Figs. 2-4.

Of this species, which, in the Pondicherri district, has only been found up to the present time in the Valudayur beds, though occurring pretty frequently in them, there lies before me a single fragment, not well preserved, but easily recognizable, from the Trigonoarca beds of Saidarampet. Several beautiful examples of the same species are in Dr. Warth's collection, from the Trichinopoli district. These come from the Ariyalūr beds of the vicinity of Otacod, from whence also Stoliczka mentions a specimen. This remarkable type is represented in France by a

¹ A. de Grossouvre, Les Ammonites de la Craie supérieure. Paris, 1893, Pl. XXXVII, Fig. 9, a, b, c.

² J. F. Whiteaves, Geol. Nat. Hist. Surv. Canada, Mesozoic Fossils, Vol. I, Pl. II. Montreal, 1879. Pl. XIII, Fig. 1.

very closely related species, *Am. haugi*, Seunes (called by Seunes¹ *Puzosia*), regarded by Grossouvre² as a stage of growth of *Lytoceras planorbiforme*, Böhm., which occurs in the upper campanian (uppermost senonian) of the Department of the Basses Pyrénées.

A description of the generic features of *Am. brahma* and the allied species *Amm. vishnu*, Forbes, and *Am. haugi*, Seunes, will be published in the second part of the researches into the cretaceous fauna of Southern India. But it may be remarked here that this group has nothing to do with *Lytoceras*, with which it has been united by Neumayr (Classification der Kreideammonites) and by Zittel (Handbuch der Palæontologie, Vol. II. genus *Lytoceras*), but is nearly related to *Holcodiscus* and *Pachydiscus*.

Locality : Pondicherri, Valudayur beds and Trigonoarca beds (Saidarampet).

NAUTILUS (HERCOGLOSSA) TAMULICUS, n. sp. Pl. VI, Figs. 5, 6 ;
Pl. VII, Fig. 1.

This species, of which I have two fragmentary examples before me, possesses strongly involute whorls, sagittate in section, which surround a very small umbilicus. The sides are without ornaments and moderately inflated, steeply inclined towards the umbilicus, near which they are widest; they converge regularly towards the periphery, which is somewhat rounded in the young, pointed in the old, shell. The septa are numerous, project towards the periphery, forming a sharp angle, and describing on the sides a deep, backwardly directed sinus, which is separated from the suture by a regularly rounded saddle. The siphuncle is situated very near the inner side, its projection would meet the turn of the curve, which the suture line describes in its transition from the side lobe to the saddle.

A related species, not yet described, occurs in the Ariyalūr beds of Kalmodu, near Otacod, but this possesses a narrower section, the keel is separated from the sides by a slight groove and is divided in the adult, so that it develops a furrow in the siphonal region.

Nautilus leiotropis, Schlüter,² from the Emscher marl of Northern Germany, is more inflated and possesses less deeply sinuated septa.

Locality. Saidarampet, Kadaperikupam ?, Nerinea beds.

The other *Nautili* belong to species which have all been described by Forbes and Blanford. There is a very fine, large specimen of *N. serpentinus*, Blanford, from the Orbitoides-bearing Nerinea limestone of Saidarampet, whilst *Nautilus danicus*, Schl., related to it, is not represented in Dr. Warth's collection. Of the species which Blanford identified with *Nautilus clementinus*, Orb. (gault), there are several badly preserved examples which agree with those of the Trichinopoli district, but are insufficient for purposes of description. But it must be pointed out that the species from both districts differ from the European species and must receive a new name.

¹ J. Seunes: Mém. Soc. Geol. de France, Paléontologie, Vol. II, No. 2, p. 20, Pl. VI, Fig. 1.

² A. de Grossouvre: Ammonites de la Craie supérieure, p. 531, Pl. XXXIV, Figs. 4, 5; Pl. XXXV, Fig. 7.

BELEMNITES, sp. ind. Pl. VI., Fig. 7, a, b.

1846. *Belemnites* (?) *fibula*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, 119, Pl. IX, Fig. 3.

From the sands of the 'Trigonoarca beds I have a single, rather eroded fragment of a belemnite,¹ which agrees with the species described by Forbes as *B. fibula*. In the phosphatic beds of the Utatur stage of Utatur, Trichinopoly district, numerous very well preserved belemnites are found, which H. F. Blanford was inclined to identify with the Pondicherri species on the ground of E. Forbes's sketch (Cret. Fauna of S. India, Vol. I., Cephalopoda, p. 3). But the section of the latter has the form of a rectangle with rounded edges, the alveolar cavity is rather long and narrow, the wall of the rostrum not smaller on the sides than in the ventral and dorsal regions. In the belemnites described from the Utatur group the section of the wall and the alveolus is oval, the latter is moreover excentric and the wall on the ventral side of the rostrum somewhat thicker. The Utatur species must therefore have a new name, whilst the specific name *fibula* had better be abandoned, as the examples known up to the present time are not sufficient for a specific diagnosis.

Locality, $\frac{1}{4}$ mile N. N. W. of Rautankupam, Trigonoarca beds.

PUGNELLUS UNCATUS, Forbes. Pl. VI, Fig. 8.

1846. *Strombus uncatus*, Forbes, Trans. Geological Society, London, 2nd ser., VII, p. 129, Pl. XIII, Fig. 16.

1847. *Strombus semicostatus*, d'Orbigny, Voyage de l'Astrolabe. Paléont. Pl. II, Fig. 38.

1867. *Pugnellus uncatus*, Stoliczka, Cret. S. India, Vol. II, p. 22, Pl. III, Figs. 9—13.

1887. *Pugnellus uncatus*, Philippi, Die tertiären und quartären, Versteinerungen Chiles. Leipzig.

This species passes up from the Valudayur beds, in which it is very common, into the Trigonoarca beds, from whence I have a well preserved cast agreeing perfectly with the typical examples, from which the shell has been broken off. *Pugnellus* is a genus which belongs in the first place to the Indo-Pacific region and is represented in the upper cretaceous of Southern India by three species (*P. uncatus*, Forb., *P. contortus*, Sow., *P. granuliferus*, Stol.); it further occurs in Natal² (*P. uncatus*), in Borneo,³ (*Pugnellus* sp., Martin), in California⁴ (*P. manubriatus*, Gabb, and *P. hamulus*, Gabb) and in Chili,⁵ (*P. uncatus*, *P. tumidus*, Gabb); but it is also known in the Colorado group of the Rocky Mountains

¹ Cl. Schlüter, Cephalopoden der oberen deutschen Kreide, I: Palæontographica, XXIV, Pl. XLVIII, Figs. 1, 2.

² C. L. Griesbach, Geology of Natal: Quart. Journ. Geol. Soc. London, XXVII, 1871, p. 61.

³ K. Martin, Die Fauna der Kreideformation von Martapoera: Sammlungen des geologischen Reichsmuseums in Leiden, IV, Nos. 5, 6, 1889, p. 188, Pl. XX, Figs. 10-12.

⁴ W. M. Gabb, Palæontology of California, Vol. I, pp. 124, 125, Pl. XVIII, Fig. 48; Pl. XX, Fig. 81; Pl. XXIX, Fig. 229.

⁵ Steinmann, Quiriquinaschichten: Neues Jahrb., Beilage Bd. X, 1, p. 96, Pl. VII, Figs. 15, 16.

region of the United States,¹ (Pugnellus sandstone), and in the Mississippi cretaceous (one species in each).

Locality, Pondicherri district, Valudayur beds, Trigonoarca beds.

GOSAVIA INDICA, Stoliczka. Pl. VII, Fig. 3, a, b.

1867. *Gosavia Indica*, Stoliczka, Cret. S. Ind., Vol. II, p. 73, Pl. VI, Figs. 3, 7, 8.

The specimens from Pondicherri agree very well with Stoliczka's figures and descriptions, but the spire appears to be a little lower than in the examples from the Trichinopoli district, which all come from the zones lying between the Trichinopoli and Ariyalūr stage. The largest of the Pondicherri examples (a fragment from Rayapudupakam) shows the numerous folds on the inner lip very well.

Locality, $\frac{1}{2}$ mile N. N. E. of Rautankupam, Valudayur beds; Rayapudupakam, Trigonoarca beds.

VOLUTILITHES MURICATA, Forbes. Pl. VII, Fig. 2.

1846. *Voluta muricata*, Forbes, Trans. Geological Society, London, 2nd ser., VII, p. 131, Pl. XII, Fig. 4.

1867. *Volutilithes muricata*, Stoliczka, Cret. S. India, Vol. II, p. 94, Pl. IX, Fig. 5.

I have figured this species again as the specimen figured by Forbes, and also that by Stoliczka, is only fragmentary; but to the description which the latter has given there is nothing to add.

Locality, $\frac{1}{2}$ mile north of Tutipet, Valudayur beds; $\frac{1}{4}$ mile west of Rautankupam, Trigonoarca beds.

HINDSIA EXIMIA, Stoliczka.

1867. *Hindsia eximia*, Stoliczka, Cret. S. India, Vol. II, p. 135, Pl. XI, Figs. 15—17.

In the Kaye and Cunliffe collection in the Museum of the Geological Society of London there is a specimen which completely agrees with this species, but has been confounded with *Polia pondicherrensis*, Forb., and has therefore not been described.

Locality, Pondicherri district, lumachelle of the Valudayur beds.

TRICHOTROPIS sp. cf. KONINCKII, Müller. Pl. VIII, Fig. 2, a, b.

From the Trigonoarca beds of Tutipet there are in the collection two phosphatized casts, retaining the sculpture of the shell, which belong to the genus *Trichotropis*, and are related to *Trich. koninckii* as well as to some other forms from the Trichinopoli district. The larger of the two specimens shows only three whorls which have two spiral ridges, the stronger of which is situated in the middle between the anterior and posterior sutures, whilst the weaker anterior one disappears under the suture and is only seen on the last whorl. Two spiral ribs are visible, one between the two ridges, another on the convex base of the last whorl. Longitudinal ribs which were probably very strong on the shell are likewise pretty distinctly marked on the cast; they form tubercles on the posterior ridge, and proceed from thence

¹ T. W. Stanton, The Colorado Formation: Bull. United States Geological Survey, No. 106, Washington, 1893, p. 148, Pl. XXXI, Figs. 7—11.

as flat prominences to the posterior suture. The aperture is oval, somewhat contracted anteriorly and posteriorly. This species is distinguished from *Trichotropis koninckii*¹ of the Achen greensand by the smaller size of the last whorl, by the shorter distance of the posterior ridge from the suture, and by the presence of spiral ribs. Holzapfel has pointed out that Stoliczka's examples² from the Trichinopoli group are different from the European species; moreover, Stoliczka has united two Indian species under the name of *Trichotropis koninckii*, to one of which (Stol., loc. cit., Pl. XIII, Fig. 7) the present specimens from Pondicherri are very similar; perhaps they should even be united with them, unless the presence of the two spiral ribs forms a special feature of the latter.

Locality, $\frac{1}{2}$ mile W. S. W. of Tutipet, Trigonoarca beds.

NERINEA, n. sp. (BLANFORDIANA, Stol.?). Pl. VII, Fig. 7; Pl. VIII, Fig. 1.

In the hard, sandy Orbitoides limestone, which overlays the Trigonoarca beds in several places, for instance at Valudayur and Saidarampet, there are found casts of large Nerineas which seem to form a special peculiarity of this horizon, for which reason I have bestowed upon it the designation Nerinea beds. But I abstain from giving a specific name, as nothing of the sculpture is to be seen, and therefore an exact comparison with described species is out of the question.

The shell is conical, not very slender, with numerous low whorls which have slightly concave sides on the cast. The base is flat and low and meets the sides in a distinct edge. The aperture is widely quadrate; two columella folds, somewhat deeply indented, are present; every whorl joins the upper part of the contiguous one with a projecting spiral rib, so that the section of each whorl, besides the two columella folds, shows a groove in the middle of the upper part and a projecting rib in the middle of the under.

There seems to be a relationship between this species and *Nerinea blanfordiana*, Stol.,³ but the want of the sculpture does not permit of any sure determination. Unfortunately Stoliczka does not figure a section of a whorl showing the folds.

As already mentioned in the geological part of this memoir, *Nerinea* occurs in the Niniyur beds (danian) of the Trichinopoli district (H. F. Blanford: Mem. Geological Survey of India, IV, p. 141), and are also several times mentioned by Stoliczka as associated with various forms of gastropods described by him; on pages 221 and 227 he even directly refers to *Nerinea blanfordiana* in the Niniyur group, whilst in the description of this species he mentions only localities from the Utatur group. An examination of the specimens in the Museum of the Geological Survey could alone elucidate this question.

The species here described differs considerably from other cretaceous Nerineas known to me.

Locality, S. S. E. of Valudayur, Nerinea beds.

CERITHIUM KARASURENSE, n. sp. Pl. VII, Figs. 5, *a*, *b*; 6, *a*, *b*.

The shell of this species is very slender, with numerous, fairly high whorls,

¹ E. Holzapfel, Die Mollusken der Aachener Kreide: Palæontographica, XXXIV, Pl. XV, Figs. 6—9, p. 149.

² F. Stoliczka, Cret. S. India, Vol. II, p. 158, Pl. XIII, Figs. 7—9.

³ F. Stoliczka, Cret. S. India, Vol. II, p. 184, Pl. XIV, Figs. 4—6.

which are scarcely at all inflated and only very slightly indented at the suture. Just below the posterior suture there is a raised rim upon which numerous rounded tubercles are seen (seventeen on the last whorl). An anterior row of tubercles, which indicates the ridge between the somewhat inflated under part and the sides, is covered by the suture and consequently is visible only on the last whorl. They are more numerous than the posterior tubercles and form the starting point for the curved longitudinal ribs, which, on the one hand pass over the sides of the whorl and can partly be traced as far as the posterior row of tubercles; on the other hand they converge towards the lower end of the aperture, getting at the same time gradually fainter. There is no spiral sculpture. The aperture is somewhat narrowed anteriorly and posteriorly; the interior end of the shell is broken off, and therefore nothing of a canal is to be seen.

In the *Orbitoides* bearing Nerinea beds of Saidarampet there occur pretty large examples of *Cerithium*, which very probably are to be identified with the species here described. The best preserved figured specimen shows, in the form of the whorls and in the sharply conical shape of the shell, a complete agreement with the example from Karasur, and possesses also a swollen ridge with rounded tubercles at the posterior suture. All other traces of sculpture are removed by weathering, but it seems as if the row of tubercles on the ridge between the sides and the base of the shell had also been there. A second example shows in section two faint columella folds. In this feature as well as in the form of the shell there is decidedly a near relationship to *Cerithium inauguratum*, Stol.,¹ but the latter may be distinguished by the presence of several spiral rows of fine tubercles as well as by the absence of the longitudinal ribs, and an anterior row of tubercles.

There is moreover in the collection worked up by Forbes also *Cerithium inauguratum*, Stol. (already thus determined by Stoliczka in his examination of the collection, but not mentioned in his publications). Another species occurring abundantly in the Ariyalūr stage—*Cerithium arcotense*, Stol. (loc. cit., p. 197, Pl. XV. Figs. 2-5)—is represented in the same collection from Pondicherri (lumachelle of the Valudayur beds).

Locality of *Cerithium karasurense*, Karasur, Trigonoarca beds; Saidarampet, Nerinea beds.

TURRITELLA WARTHI, n. sp. Pl. VIII., Fig. 3, *a*, *b*.

A very slender form with regularly convex whorls, which are separated from each other by a somewhat deeply indented suture, and are distinguished by a very, fine, regular, spiral sculpture. Three of the spiral lines in the middle of the whorl are more distinct.

Related to this species is *Turritella ventricosa*, Forbes (loc. cit., p. 123, Pl. XIII, Fig. 3), which, however, increases considerably quicker, and has a somewhat coarser sculpture; the species from Niniyur, which Stoliczka has identified with *Turr. ventricosa*, differs greatly.

Very similar to this species is *Turritella quadricincta*, Goldfuss, from the German senonian (E. Holzapfel: Palæontographica, XXXIV, Taf. XV, Fig. 16.); but it has four instead of three coarser spiral lines. *Turritella meadii*, Baily, from

¹ F. Stoliczka, Cret. S. Ind., Vol. II, p. 193, Pl. XV, Figs. 15, 19, 20.

Natal (Quart. Journ. Geol. Soc., London, 1855, p. 458, Pl. XII, Fig. 6), shows stronger longitudinal lines and more numerous spiral ribs.

Locality, $\frac{1}{2}$ mile north and 1 mile N. N. W. of Tutipet, Valudayur beds.

TROCHUS ARCOTENSIS, Forbes. Pl. VIII, Fig. 4, *a, b, c*.

1846. *Trochus Arcotensis*, Trans. Geol. Soc., London, 2nd ser., VII, p. 119; Pl. XIII, Fig. 9.

The specimens of *Tr. arcotensis* from Pondicherri which I have before me (Forbes's specimens come also from there) differ from the highly ornamented *Tr. geinitzianus*, from the Bohemian cretaceous, with which Stoliczka united it, as well as from the examples identified with them from the Trichinopoli district. The spiral sculpture is very faint, the outer ridge of the whorls without tubercles and not sharp; that part of the shell between it and the suture is inflated, not simply roof-like, as in Stoliczka's examples, which indeed come very near to *Tr. geinitzianus* (loc. cit., Vol. II, Pl. XXIV, Figs. 11—15.)

Very nearly related to *Trochus arcotensis* is a species from Natal, which Baily has named *Solarium pulchellum* (Quart. Journ. Geol. Soc., London, 1855, p. 458, Pl. XII, Fig. 3), but the height of the spire is somewhat less. In the lumachelle of the Trichinopoli stage of Garudamangalam two species of *Trochus*, not yet described, occur, of which one is very similar to *Tr. arcotensis*, but has a sharp outer ridge, and the upper part of the whorl is not inflated, but roof-like.

Locality, $\frac{1}{2}$ mile N. W. and north of Tutipet, etc., Valudayur beds.

TEINOSTOMA CRETACEUM, d'Orbigny. Pl. VIII, Fig. 5, *a, b, c*.

1867. *Teinostoma cretaceum* (d'Orbigny) Stoliczka, Cret. S. Ind., Vol. II, p. 350, Pl. XXV, Fig. 7.

The extremely small species described by d'Orbigny from Pondicherri, and figured by Stoliczka from the Ariyalur stage of Comarapalaia, is very common and always beautifully preserved in the lumachelle of the Valudayur beds, so that the brownish, radiating colour bands are often to be seen on the shiny, porcelainous shell.

Locality, $\frac{1}{2}$ mile north of Tutipet, Valudayur beds.

BULLINA CRETACEA, d'Orbigny. Pl. VIII, Fig. 6, *a, b*.

1847. *Bulla cretacea*, d'Orbigny, Voyage de l'Astrolabe. Paléontologie, Pl. III, Figs. 18—21.

1867. *Bullina cretacea*, Stoliczka, Cret. S. Ind., Vol. II, p. 414 (non Pl. XXVII, Fig. 19).

Small examples of *Bullina* are among the most common fossils in the Valudayur beds, and particularly one species which d'Orbigny describes as *B. cretacea*. A special feature of this form is the striking thickening of the lines of growth at the upper end of the cylindrical shell which there develop into slight folds. In the examples from Garudamangalam, which Stoliczka figured as *B. cretacea*, this feature is not present, moreover they are more distinctly spirally striated and attain a somewhat larger size.

Besides *Bullina cretacea* there occurs in Pondicherri another species, Pl. VIII, Fig. 7, *a, b*, ornamented with fine, spiral lines, which does not show the posterior thickening of the lines of growth, is very slender, but has not a cylindrical shape; it

is considerably narrowed posteriorly, whilst the sides are slightly inflated. This form might be perhaps identical with the slender variety of *Bullina alternata*, Forb., which Stoliczka (loc. cit., Pl. XXVII, Fig. 18) figures from the upper Trichinopoli stage of Varagur.

Locality, N. N. W. of Tutipet, $\frac{1}{2}$ mile north of Tutipet, etc., Valudayur beds.

EUPTYCHA LARVATA, Stoliczka. Pl. VII, Fig. 4, a, b.

1867. *Euptycha larvata*, Stoliczka, Cret. S. Ind., Vol. II, p. 426, Pl. XXVI, Fig. 6.

The two phosphatized examples from Pondicherri agree entirely with Stoliczka's type specimen from Comarapalaia.

Locality, Rayapudupakam, Trigonoarca beds.

DENTALIUM CRASSULUM, Stoliczka. Pl. VIII, Fig. 8, a, b.

1867. *Dentalium crassulum*, Stoliczka, Cret. S. Ind., Vol. II, p. 444, Pl. XXVII, Fig. 21.

This species was described by Stoliczka from the upper Trichinopoli stage of Serdamangalam, but I have it also from the lumachelle of the lower Trichinopoli stage of Garudamangalam; also from the white sands of the Ariyalūr stage of Karapadi, and one example with completely similar features from the Valudayur beds of Pondicherri.

Dentalium arcotinum, Forb., also frequently occurring in Pondicherri, is common to the Trichinopoli and Ariyalūr groups, as numerous examples from Garudamangalam are present, which I cannot distinguish from the Pondicherri ones.

Locality, 1 mile N. N. W. of Tutipet, Valudayur beds.

PHOLADOMYA LUCERNA, Forbes. Pl. VIII, Figs. 9, 10, a, b.

1846. *Cardium lucerna*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, Pl. XVII, Fig. 10.

1871. *Pholadomya caudata*, Stoliczka (non Römer), Cret. S. Ind., Vol. III.

This species is distinguished from *Pholadomya caudata*, Römer (Verstein. des norddeutschen Kreidegebirges, Hannover, 1841, p. 76, Taf. X, Fig. 8), by the less strongly curved lower margin, and the almost equally rounded anterior and posterior sides, of which the latter is not so strikingly narrowed as in the examples from the German senonian.

Locality, Pondicherri district, Pulichapalaia, Tutipet, Rautankupam, Horizon B and C.=Valudayur beds; Tutipet, Rautankupam, Trichinopoli district, Trigonoarca beds of Parcheiri and Serdamangalam, upper Trichinopoli stage (rep. lower Ariyalūr stage).

CORBULA PARSURA, Stoliczka. Pl. IX, Fig. 11, a, b.

1871. *Corbula parsura*, Stoliczka, Cret. S. Ind., Vol. III, p. 44, Pl. I, Figs. 23, 24; Pl. XVI, Figs. 3, 4.

1893. *Corbula parsura*, F. Kossmat, Einige Kreideversteinerungen vom Gabun (Sitzber. d. k. Akad. d. Wiss., Wien, 1893), p. 579, Taf. I, Fig. 3, a, b, c.

Of this easily recognized species there was found in the Valudayur beds a small example, about 3 mm. long, which agrees with the described type specimens from the lumachelle of Garudamangalam (Trichinopoli stage), as well as with the figured specimen from the upper cretaceous of Gabun (West Africa) in the pecu-

liarily thick form of the shell and the strong concentric folds. The circumstance is of special importance that this species, the only one from the upper cretaceous of the Gabun, which is to be identified with one already described, passes up into the upper senonian in India, for I was formerly already of opinion that the fauna of the calcareous marl of the Gabun according to its general habit (*cf.* for example *Echinobrissus atlanticus*, Koss.) belongs rather to the senonian than to the turoonian, a determination of age, which thus now no longer contradicts the fact of the occurrence of *Corbula parsura*.

Locality, $\frac{1}{2}$ mile north of Tutipet, Valudayur beds.

TELLINA PONDICHERRENSIS, Forbes. Pl. IV, Figs. 13, 14, *a*, *b*.

1846. *Tellina?* *pondicherrensis*, Forbes, Trans. Geol. Soc., London, 2nd Ser., VII, p. 142, Pl. XVIII, Fig. 15.

Non 1871. *Baroda* (*Icanotia*) *pondicherrensis*, Stoliczka, Cret. S. Ind., Vol. III, p. 167, Pl. IV, Fig. 5; Pl. XVII, Fig. 4.

Of this species, which was described by Forbes as *Tellina?*, but belongs certainly to this genus, I have before me several rather well preserved examples, which are all distinguished by the somewhat long, narrow shape of the shell, similarly rounded anterior and posterior margins, as well as the almost straight lower margin. The umbones are pointed, placed far forward towards the anterior end: the shell is thin and provided with only fine lines of growth. *Baroda pondicherrensis*, Stol., from the Utatur stage, which was identified with this species, has a thicker shell, stronger lines of growth, and further shows fine lines radiating from the umbones.

Locality, $\frac{1}{2}$ mile north of Tutipet, Valudayur beds.

TELLINA (ARCOPAGIA) FORBESIANA, n. sp. Pl. IX, Fig. 12, *a*, *b*, *c*.

The figured left valve of this species, very slightly inflated, has a somewhat long form, a narrow anterior, and a broad posterior side, with the umbo placed in the middle. The posterior part of the shell flattens towards the broad, rounded posterior margin, and shows extremely fine striation, radiating from the umbo and producing quite a delicate network of thin lines of growth, which disappear before they reach the margin. The dentition is unknown. In the related species, *Arcopagia gabunensis*, Kossmat¹ from the upper cretaceous of the Gabun, the shell is posteriorly about the same width as anteriorly, the concentric sculpture consists of raised lines, closely and regularly placed together, the radiating striæ near the posterior margin are more perceptible. *Tellina monilifera*, Gabb,² from the Martinez group of California is more inflated and has a rather strongly curved lower margin as well as a narrow, rounded posterior margin. Among the Indian species there is none which would require a close comparison with the described species.

Locality, 1 mile N. N. W. of Tutipet, Valudayur beds.

¹ F. Kossmat, Sitzungsberichte d. k. Akad. d. Wiss., Wien, 1893, p. 580, Taf. I, Fig. 7, *a*, *b*,

² Palæontology of California, Vol. I, p. 157, Pl. XXII, Fig. 134.

TRIGONOARCA GALDRINA, d'Orbigny. Pl. IX, Figs. 1—3.

1847. *Arca galdrina*, d'Orbigny, Voyage de l'Astrolabe et de la Zélée. Paleontologie, Pl. V, Figs. 32, 33.

1871. *Trigonoarca galdrina*, Stoliczka, Cret. S. Ind., Vol. III, p. 355, Pl. XVIII, Figs. 2-5.

As this species, which occurs in numerous examples in the middle horizons of the cretaceous of Pondicherri, but also begins to appear isolated in the Valudayur beds, is only mentioned by Stoliczka from the Ariyalūr stage of Serdamangalam and Sripermatūr, outside this district, whilst examples from Pondicherri are figured only in d'Orbigny's rare book, I show a few figures of well preserved examples on Plate IX. There is nothing to add to Stoliczka's description. In the related species *Trigonoarca gamana*, Forbes, from Pondicherri (loc. cit., Pl. XVI, Fig. 3), the space between the posterior margin and the keel which runs downwards from the umbo, is simply rounded, and shows neither the strong middle rib nor the fine radiating lines which characterize this part of the shell in *Trigonoarca galdrina*. *Trigonoarca gamana*, Stoliczka (non Forb.), (loc. cit., Pl. XX, Figs. 4, 5, Pl. L, Fig. 7), from the Utatur stage, differs from both the species named by the thicker shape, and above all by the posterior side being proportionally much wider than the anterior; this must therefore always be treated as a distinct species.

Locality, Pondicherri district, Valudayur and Trigonoarca beds.

PLICATULA SEPTEMCOSTATA, Forbes. Pl. X, Fig. 1.

1846. *Plicatula septem-costata*, Forbes, Trans. Geol. Soc., London, 2nd ser, VII, p. 155, Pl. XVIII, Fig. 4.

The two valves of the figured example are about oval in outline, irregularly lengthened in the region of the umbo; the lower valve is moderately convex, the upper somewhat concave near the umbo. Both are covered with strong, raised ribs, which bear numerous scaly lamellæ, corresponding with the thicker lines of growth. On Forbes's example only the latter are to be seen, whilst nothing is to be observed of the lamellæ upon the ribs, evidently because the upper layer of the shell is wanting. (In the oysters from the Valudayur beds the outer rough layer of the shell is nearly always lost in developing and only the inner pearly layer remains.)

Locality, $\frac{1}{2}$ mile W. S. W. of Tutipet, Trigonoarca beds. Forbes's example, judging from the mode of preservation, came from the Valudayur beds.

SPONDYLUS LAMELLOSUS, n. sp., Pl. IX, Fig. 10, *a*, *b*.

This species, related to *Spondylus calcaratus*, Forb., which does not seem to be rare in the Trigonoarca beds, is distinguished by a very peculiar ornamentation. The surface of the shell has radiating folds, with numerous close set ribs having the same direction as the folds and covering them as well as the furrows between. Alternating, strong, concentric lamellæ, arise at irregular distances from one another, but soon fade away at each end. The outline of the shell is roundish, very similar to that of *Spondylus calcaratus*, but there is no example showing the umbonal region. An example of the last-named species, which Stoliczka (loc. cit., Pl. XXX, Fig. 7*a*) figures, shows also some resemblance in the ornamentation, but the ribs are somewhat finer, and instead of the strong lamellæ there are only irregular concentric folds.

Locality, Saidarampet, $\frac{1}{4}$ mile west of Rautankupam, etc., Trigonoarca beds.

The following species, not previously known from Pondicherri, are only figured to show the agreement with forms from the Trichinopoli district :—

Siliqua limata, Stol. (Vol. III, Pl. I, Figs. 12, 13), Pl. IX, Figs. 4, 5.

Pharella delicatula, Stol. (Vol. III, Pl. I., Fig. 14), Pl. IX, Fig. 8.

Baroda elicita, Stol. (Vol. III, Pl. IV, Fig. 16), Pl. IX, Fig. 7.

Cyprina cristata, Stol. (Vol. III, Pl. IX, Fig. 1), Pl. IX, Fig. 9.

Hippagus æmilianus, Stol. (Vol. III, Pl. XIV, Fig. 6), Pl. IX, Fig. 6.

Spondylus ariyalurensis, Stol. (Vol. III, Pl. XXXIII, Fig. 5), Pl. X, Fig. 2.

TEREBRATULA ARABILIS, Forbes. Pl. V, Fig. 4, *a f.*

1846. *Terebratula arabilis*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, p. 138, Pl. XVIII, Fig. 12.

This species has a broad oval shape and pretty regularly inflated valves; the foramen, which truncates the umbo of the larger valve, is proportionally small, the lateral elevations proceeding from it are rounded. The line of junction of the two valves is slightly curved, a single broad sinus, directed towards the smaller valve, is present. The delicately punctured surface of the shell shows extraordinarily fine lines of growth. Where this very fine outer layer is flaked off, another layer appears, which is distinguished by its silky gloss, and shows in the umbonal region fine radiating lines, and instead of the lines of growth is marked by very regular concentric bands, which are not in relief but form part of the structure of the shell. One sees, namely, with a lens, that each band consists of scale like lamellæ, lying one upon another, and that the imbrication of the scales is opposite in two of the contiguous bands. Consequently those bands in which the imbrication of the lamellæ is turned towards the light always show a peculiar, silky gloss. This shell structure is not known in *Terebratula depressa*, Lam., var. *cyrtæ*, Walker, which Stoliczka figured from the Utatur group (loc. cit. Vol. IV, Pl. II, Figs. 7-8) and among whose synonyms he also placed *Terebratula arabilis*; further the foramen is larger and the elevation of the valves somewhat greater, and there are among the lines of growth some developed into somewhat rugose thickenings. I consider therefore the two species to be different.

Locality, $\frac{1}{4}$ mile west of Rautankupam, Trigonoarca beds.

TEREBRATULA BIPLICATA, Sowerby. Pl. X, Fig. 3, *a, c.*

1873. *Terebratula biplacata*, Stoliczka, Cret. S. India, Vol. IV, Pt. I, p. 19, Pl. IV, Figs. 2-17.

The present species represented by a single example agrees completely with the type which Stoliczka has designated var. *karapaudensis* (Stol., loc. cit., Pl. IV, Figs. 5-9; the greatest resemblance is with figure 8).

Locality, $\frac{1}{4}$ mile west of Rautankupam (Trigonoarca beds).

HEMIASTER PULLUS, Stoliczka. Pl. X, Fig. 6, *a—d.*

1873. *Hemiasler pullus*, Stoliczka, Cret. S. Ind., Vol. IV, Pt. III, p. 18, Pl. II, Figs. 8, 9.

The little species of *Hemiasler*, from the Ariyalûr stage of Ariyalûr, which has been recorded and very minutely described, but not very well figured by Stoliczka,

does not appear to be rare in the Trigonoarca beds, as there are in Warth's collection six specimens, mostly very well preserved, which agree remarkably with Stoliczka's types. The figured example (the largest among the present ones) shows the peculiar form of the rather deeply depressed ambulacral zones very distinctly; the elevation between the two posterior, short ambulacra is here somewhat more distinct than in the smaller specimens (see also Stol., Pl. II, Fig. 8, *b.*), without, however, developing a sharp ridge, as in *Hemiaster cristatus*, Stol.

Locality, $\frac{1}{4}$ mile west of Rautankupam, Trigonoarca beds.

HEMIASTER TAMULICUS, n. sp. Pl. V, Fig. 5, *a—d.*

This species shows a tolerably regular oval outline, regularly rounded sides, and a proportionally inflated lower side. The part lying behind the subcentral (somewhat nearer the posterior side) apex is distinctly higher than the part in front, inclining at first steeply, and overhanging in the region of the anus. The whole surface is covered with closely set granules, which are largest near the mouth. The ambulacra are depressed to a moderate depth and somewhat narrow. The anterior furrow is the longest but disappears before it reaches the periphery; the two ambulacral furrows on each side of it diverge from one another at an angle of about 90° , are very little curved, broadly club-shaped and show about 16 pairs of pores. The posterior ambulacra are oval, considerably shorter than all the others and separated from each other by a rounded elevation. The ambulacral region is surrounded by a fasciole, which, owing to the considerable length of the anterior furrow, appears to be much elongated. The new species is very easily distinguished from the one associated with it, *Hemiaster pullus*, Stol., by the simple oval outline, the slight depth of the ambulacra, and the narrowness of the anterior furrow, which does not reach the margin. Among the remaining forms of the Indian cretaceous there is none with which this species could be confounded.

The related species *Hemiaster soulicri*, Fallot,¹ from the senonian beds of Dieulefit (France), is proportionally less high, the anterior ambulacra are broader and longer.

Locality, $\frac{1}{4}$ mile west of Rautankupam, Trigonoarca beds.

Animal groups other than those above described are only sparingly represented in the fauna of Pondicherri.

Of bryozoa there is only one species (*Lunulites*, sp.). Corals are very rare, and owing to the sandy nature of the matrix, mostly badly preserved; annelids are represented by two species, *Ditrupa longissima*, Forbes, and *Serpula filiformis*, Sow., the latter of which (Pl. X, Fig. 7) was also known in the Ariyalur stage of Karapadi.

On the other hand, the sandy limestone of the Nerinea beds of the uppermost division of the cretaceous is completely filled with well preserved foraminifera among which the genus *Orbitoides* (Pl. X, Figs. 8-10) is particularly striking by its great frequency. As Stoliczka was also able to prove the existence of this genus in the Niniyur beds of Niniyur, Trichinopoli district (*Orbitoides faujassi*,

¹ Fallot, Terr. crétacée dans le Sud—Est de la France : Annales des. Sciences Géologiques. Paris, XVIII, 1885. p. 258, Pl. VIII, Figs. 2, 3.

Lam.; Stol., Cret. S. Ind., Vol. IV, Pt. IV, p. 61, Pl. XII, Figs. 3-5), this circumstance increases the agreement which exists already elsewhere between the two groups of beds. Of other sections of foraminifera a few are specially remarkable; they seem to indicate the genus *Amphistegina* (Pl. V, Figs. 11, 12).

GENERAL LIST OF PONDICHERRI FOSSILS.

The following list comprises, besides the fossils represented in Dr. Warth's collection also those described by Forbes, d'Orbigny and Stoliczka. A reference to the descriptions and figures of them by the individual authors is, I think, not necessary, as they are all easily to be found in the complete list of Stoliczka's Monograph. Species which are not known for certain to have been found in Pondicherri (as, for instance several echinoderms described by Forbes) are not taken into consideration. The arrangement of the Pondicherri cretaceous into three different horizons succeeded tolerably well with all the more important fossils, especially in the greater number of species established by Forbes, which I myself had the opportunity of seeing. As to the fossils described by Stoliczka, the remarks made by him upon the character of the rock and the association of the fossils are in the most cases sufficient to enable the horizon to be recognized. D'Orbigny's species, putting aside those found also in more recent collections, could not be provided with a definite horizon. In the table of foreign localities the description of the species compared could not be cited for want of space; I therefore quote here the works in which the most important are to be found; others are mentioned in the palæontological part of this paper.

The following is a list of the principal papers containing descriptions and figures of the foreign fossils, mentioned in the following table of the Pondicherri cretaceous fauna:—

EUROPE		<i>A. de Grossouvre</i> , Les Ammonites de la Craie supérieure: Mémoires pour servir a l'explication de la Carte géologique détaillée de la France. Paris, 1893. <i>A. d'Orbigny</i> : Prodrôme de Paléontologie, Paris, 1852. Vol. II., „ „ Terrains Crétacés, Paléontologie Française.
NATAL		<i>C. L. Griesbach</i> , Geology of Natal: Quart. Journ. Geol. Soc., London, XXVII, 1871, p. 60 ff.
YESSO		<i>M. Yokoyama</i> , Verstein. a. d. Japan. Kreide: Palæontographica, XXXVI, 1890. <i>K. Yimbo</i> , Kreideformat. v. Hokkaido: Palæontologische Abhandlungen, VI. pt. 3. Jena, 1894.
VANCOUVER		<i>T. F. Whiteaves</i> , on the Fossils of the Cretaceous Rocks of Vancouver and adjacent Islands: Geol. and Nat. Hist. Surv., Canada. Mesozoic Fossils, Vol. II. Montreal, 1879.
QUIRIQUINA ISLAND		<i>G. Steinmann</i> , Das Alter und die Fauna der Quiriquinaschichten in Chile: Neues Jahrbuch, Beilageband, X. Stuttgart, 1895.

NAME.	PONDICHERRI DISTRICT.			TRICHINOPOLI DISTRICT.		Foreign localities.	Agé.
	Valdayur-beds.	Trigonocarcabeds.	Nerineabeds.	Locality.	Stage.		
<i>Phylloceras surya</i> , Forbes . . .	x	...	...	. . . . .	..	S. Vincente (Chile) . . .	Upp. senon.
" <i>nera</i> , Forbes . . .	x	...	...	. . . . .	...	Vancouver; allied species in Japan, Quiriquina Island, Europe.	Senon.
" <i>decipiens</i> , Koss. . .	x						
" <i>forbesianum</i> , Koss. . .	x	...	...	A nearly allied species at Odiam.	U	Vancouver	Upp. senon.
<i>Lytoc. (Gandryceras) kayei</i> , Forbes .	x	...	...	. . . . .	.	Natal, Quiriquina Island; allied species in Vancouver and Europe.	Upp. senon.
" " <i>valdayurensis</i> , Koss. .	x	.					
" " <i>varuna</i> , Forbes. .	x	...	...	. . . . .	...	Quiriquina Island	Upp. senon.
" (Tetragonites) <i>cala</i> , Forbes .	x	x					
" (Pseudophyllites) <i>indra</i> , Forbes.	x	...	...	. . . . .	...	Natal, Vancouver; allied: <i>A. colloti</i> , Gross, in France.	Upp. senon.
<i>Anisoceras indicum</i> , Forbes . . .	x	?	● ...	Odiam?	U?		
" <i>subcompressum</i> , Forbes . .	x						
" <i>largesulcatum</i> , Forbes . .	x	...	...	. . . . .	...	<i>Hamites</i> sp. Jimbo, loc. cit. pl. VII, fig. 7 (Yesso).	?
" <i>tenuisulcatum</i> , Forbes . .	x	...	...	Olapadi (not figured) . . .	A		
" <i>rugatum</i> , Forbes . . .	x	...	...	. . . . .	...	Allied species occur in Vancouver, Quiriquina, Yesso, Europe (<i>H. cylindraceus</i>).	Upp. senon.

"	<i>neries</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>undulatum</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>sp. nov. ind.</i> , Stol.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Ptychoceras</i>	<i>sipho</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Baculites</i>	<i>teres</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>vagina</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>vagina</i> , var. <i>otacodensis</i> , Stol.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Sphenodiscus</i>	<i>sina</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Holcodiscus</i>	<i>indicus</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Holcodiscus</i>	<i>sp. nov.</i> (undescribed, coll. Kaye).	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Amm.</i> (n. g.)	<i>brahma</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>vishnu</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
<i>Pachydiscus</i>	<i>ganesa</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>egertoni</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>crishna</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>gollevillensis</i> , Orb.	.	...	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>sp. ind.</i>	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.
"	<i>menu</i> , Forbes.	.	x	...	.	.	.	.	.	...	Upp. senon.	Quiriquina Isl.; allied species in Europe, Vancouver, etc.

Abbreviations: U=Utatur stage. T=Trichinopoli stage. A=Ariyalur stage.

NAME.	PONDICHERRI DISTRICT.			TRICHINOPOLI DISTRICT.		Foreign localities.	Age.
	Valudayur beds.	Trigonarca beds.	Nerinea beds.	Locality.	Stage.		
<i>Puzosia rembda</i> , Forbes . . .	x	..	..	Allied to <i>Puzosia gardeni</i> , Baily, (Karapadi, etc.)	A	Natal; allied species in Vancouver, Yesso, Europe.	Upp. senon.
<i>Desmoceras yama</i> , Forbes . . .	x	..	..	Otacod	A	Allied to <i>Am. selwynianus</i> , Whiteaves, Vancouver.	Upp. senon.
" <i>diphyllode</i> , Forbes. . .	x	..	..	. . . . .	...	Allied to <i>Scaphites constrictus</i> Sow, Europe.	Senon.
<i>Scaphites cunliffei</i> , Forbes. . .	x	..	..	. . . . .			
" <i>pavana</i> , Forbes . . .	x	..	..				
<i>Nantilus valudayurensis</i> , Forbes .	x	..	..				
" <i>sphaericus</i> , Forbes . . .	..	..	x	Ariyalur, Shillagadi, etc. . .	A		
" <i>sp. nov. (clementinus, Blanf.)</i>	..	x	..	Ariyalur, Karapadi, etc. . .	A		
" <i>sublaevigatus</i> , Orb. . .	..	x	..	Ariyalur, Shillagadi . . .	A	Europe	Turon.
" <i>danicus</i> , Schl.	..	..	x	Niniyur, Senthuray . . .	A	Europe	Danian.
" <i>serpentinus</i> , Blanf. . .	..	..	x				
" <i>tamulicus</i> , Koss.	..	..	x				
" <i>(Aturia) delphinus</i> , Forbes.	..	..	?				
<i>Belemnitæ sp.</i>	..	x	..				
<i>Pugnellus uncatæ</i> , Rorbes . . .	x	x	..	Ariyalur, Kalligadi, Anapadi, etc.	A, T	Quiriquina Island . . .	Upp. senon.
<i>Aporrhais securifera</i> , Forbes . .	x	..	..	Ariyalur, Karapadi, Anapadi, etc.	A, T		

<i>Rostellaria palliata</i> , Forbes	.	.	x	...	Ariyalúr, Karapadi, Serdaman- galam, etc.	A, T
<i>Cypræa nemboldi</i> , Forbes	.	.	...	...	Andur, Kalligadi	A, T
" <i>cunliffei</i> , Forbes	.	.	...	...	Varagur	A
" <i>globulina</i> , Stol.	.	.	...	...		
" <i>bayei</i> , Forbes	.	.	...	...	Ariyalúr, Andur, etc.	A, T
<i>Dipsacus vetustus</i> , Forbes	.	.	x	...		
<i>Gesavia indica</i> , Stol.	.	.	x	...	Kalligadi, Serdamangalam, etc.	A, T
<i>Melo pyriformis</i> , Forbes	.	.	?	...	Kalligadi	A
<i>Ficulopsis pondicherrensis</i> , Forbes	.	.	x	...	Kalligadi	A
<i>Athleta purpuriformis</i> , Forbes	.	.	x	...	Kalligadi, Varagur	A, T
<i>Volutilithes muricata</i> , Forbes	.	.	x	...	Kalligadi	A
" <i>radula</i> , Forbes	.	.	x	...	Kalligadi	A
" <i>septemcostata</i> , Forbes	.	.	?	...	Ariyalúr	A
<i>Triton alatus</i> , Forbes	.	.	?	...		
<i>Hindsia eximia</i> , Stol.	.	.	x	...	Ariyalúr, etc.	A
<i>Mitreola eltharina</i> , Forbes	.	.	x	...		
<i>Hemifusus cinctus</i> , Forbes	.	.	?	...	Andur, etc.	T
<i>Pollia pondicherrensis</i> , Forbes	.	.	x	...	Anapadi, Varagur	T
" <i>fluctuosa</i> , Forbes	.	.	...	...		
<i>Neptunea (?) subbuccinoides</i> , Orb.	.	.	?	...		
<i>Trichotropis</i> , sp.	.	.	...	...		
<i>Cancellaria breviplicata</i> , Forbes	.	.	?	...	Ariyalúr, etc.	A
" <i>camdeo</i> , Forbes	.	.	?	...	Comarapalaiaam	A

NAME.	PONDICHERRI DISTRICT.			TRICHINOPOLI DISTRICT.		Foreign localities.	Age.
	Valudayur beds.	Trigonoarca beds.	Nerinea beds.	Locality.	Stage.		
<i>Nerinea</i> sp.	...	...	x	Niniyur?	A?		
<i>Cerithium arcotense</i> , Forbes	x	...	...	Cuthur, Otacod, etc.	A		
" <i>goharuliiferum</i> , Forbes	?	...	...				
" <i>scalaroidium</i> , Forbes	x	...	...	Ariyalūr, Comarapalaia	A		
" <i>fontanieri</i> , Orb.	?	...	...				
" <i>karasurense</i> , Koss.	...	x	?				
" <i>inauguratum</i> , Stol.	...	?	...	Comarapalaia, Karapadi, etc.	A		
<i>Turritella pondicherrensis</i> , Forbes	x	?	...	Ariyalūr	A		
" <i>ventricosa</i> , Forbes	x	...	...				
" <i>breantiana</i> , Urb.	...	x	...	Otacod, Sripermatūr, Varagur	A, T	Natal	Senon.
" <i>warthi</i> , n. sp.	x	...	...			Allied to <i>T. quadricincta</i> Goldf. (Germany).	Senon.
<i>Scala subturbinata</i> , Orb.	...	?	...	Ariyalūr	A		
<i>Vermiculus anguis</i> , Forbes	x	...	...				
<i>Eulima antiqua</i> , Forbes	x	...	...				
<i>Euspira pagoda</i> , Forbes	x	x	...	Andur	A		
" <i>obliquistriata</i> , Forbes	...	?	...				
<i>Gyrodes munitus</i> , Forbes	...	?	...				
<i>Tectura (?) elevata</i> , Forbes	x	...	...				
<i>Helcion corrugatum</i> , Forbes	x	...	...				

<i>Nerita divaricata</i> , Orb.	x	x	...	Parcheri	A			
<i>Phasianella incerta</i> , Forbes	x	x	...	Karapadi, Varagur, etc.	A, T			
<i>Uvanilla rajah</i> , Forbes	x							
<i>Trochus arcotensis</i> , Forbes	x							
<i>Teinostoma cretaceum</i> , Orb.	x	x	...	Comarapalaia	A			
<i>Solaricella radiatula</i> , Forbes	x	x	...	Ariyalur, Karapadi, etc.	A		Sachalin, Europe (Aachen)	Senon.?
<i>Delphinula</i> (?) <i>rotelloides</i> , Forbes	x							
<i>Bullina cretacea</i> , Orb.	x							
" <i>alternata</i> , Orb.	x	x	...	Garudamangalam, Varagur	T			
" <i>sp.</i>	x							
<i>Bullinula obtusiuscula</i> , Stol.	?		...	Ariyalur	A			
<i>Acteon curculio</i> , Forbes	x	x	...	Comarapalaia	A			
<i>Acteonina columnaris</i> , Stol.	x							
<i>Ringicula latirostris</i> , Forbes	x	x	?	N. of Karapadi	A			
<i>Emptycha larvata</i> , Stol.		x	x	Comarapalaia	A			
" <i>oviformis</i> , Forbes	?		...	Serdamangalam, Koloture	T			
<i>Leptomario indica</i> , Forbes	?		...	Ariyalur, Comarapalaia, Odiam?	A, U?			
<i>Dentatium arcotinum</i> , Forbes	x	x	...	Garudamangalam	T			
" <i>crassulum</i> , Stol.	x	x	...	Ariyalur, Garudamangalam	A, T			
<i>Fustiaria parvula</i> , Stol.								
<i>Teredo glomerans</i> , Stol.	...		x	Comarapalaia	A			
<i>Gastrochæna aspergilloides</i> , Forbes	?							
<i>Clavagella semisulcata</i> , Forbes	x							
<i>Corbula parsura</i> , Stol.	x	x	...	Garudamangalam	T		Gabon (W. Africa)	Senon.

NAME.	PONDICHERRI DISTRICT.			TRICHINOPOLI DISTRICT.		Foreign localities.	Age.
	Valdayur beds.	Trigonarca beds.	Nerinea beds.	Locality.	Stage.		
<i>Corbula</i> cf. <i>striatuloides</i> , Forbes	x	...	...	Garudamangalam . . .	T	Allied to <i>P. papyracea</i> , Böhm. (Maëstricht, Aachen).	Senon, Danien.
„ <i>minima</i> , Orb.	?	...	...	Odiam . . .	U		
<i>Neera mutua</i> , Stol.	x	...	...	S. of Parcheri . . .	A		
<i>Peromya lata</i> , Forbes	x	...	...	Garudamangalam . . .	T		
„ <i>globulosa</i> , Forbes	?	...	...	Comarapalaiaim . . .	A		
<i>Corimya pertusa</i> , Stol.	x					Allied to <i>Ph. caudata</i> , Römer (Germany).	Senon.
<i>Ceromya subsinuata</i> , Forbes	x	x					
<i>Anatina arcuata</i> , Forbes	x						
<i>Pholadomya lucerna</i> , Forbes	x	x	...	Parcheri, Serdamangalam . . .	A, T		
„ <i>connectans</i> , Forbes	x						
<i>Panopæa orientalis</i> , Forbes	x	x	...	Ariyalûr, Serdamangalam . . .	A, T		
<i>Siliqua limata</i> , Stol.	x	...	...	Parcheri, Serdamangalam . . .	A, T		
<i>Pharella delicatula</i> , Stol.	x	...	...	Parcheri . . .	A		
„ <i>obscura</i> , Forbes	x						
<i>Tagelus albertinus</i> , Orb.	?	...	...	Comarapalaiaim . . .	A		
<i>Tellina pondicherrensis</i> , Forbes.	x						
„ <i>forbesiana</i> , n. sp.	x						
<i>Baroda elicta</i> , Stol.	x	...	...	Karapadi . . .	A		
<i>Thetironia ignobilis</i> , Stol.	x						

	x	...	...	Ariyalūr	...	A	
<i>Cyprina cristata</i> , Stol.	.	.	.	Niniyur	.	A	
<i>Cyprimeria obesa</i> , Orb.	.	.	.	Vailapadi, Anapadi	.	T	
<i>Cardium cf. pullatum</i> , Forbes	.	.	.	Mongalpadi	.	U	
<i>Protocardium bisectum</i> , Forbes	.	.	.	Anapadi, etc.	.	T	
" <i>pondicherrense</i> , Forbes.	.	.	.	Maravattur, Niniyur	.	U, A	
<i>Lucina fallax</i> , Forbes	.	.	.	Sripermatūr	.	A	
<i>Hippagus amilianus</i> , Stol.	.	.	.	Odiam	.	U	
<i>Grobiana jugosa</i> , Forbes	.	.	.	Niniyur	.	A	
<i>Cardita orbicularis</i> , Forbes	.	.	.	Comarapalaia	.	A	
" <i>striata</i> , Forbes	.	.	.	Karapadi	.	A	Upp. senon.
<i>Trigonia orientalis</i> , Forbes	.	.	.	Niniyur	.	A	
" <i>suborbicularis</i> , Forbes	.	.	.	Kananor	.	A	
<i>Yoldia striatula</i> , Forbes	.	.	.	Ariyalūr	.	A	
<i>Nucula indefinita</i> , Forbes	.	.	.	Odiam, Serdamangalam	.	U, T	
<i>Axinea subauriculata</i> , Forbes	.	.	.	Ariyalūr, Otacod	.	A	Sachalin ?
" <i>levicula</i> , Stol.	.	.	.	Serdamangalam, Sripermatūr	.	A	
" <i>cardioides</i> , Orb.	.	.	.	Serdamangalam	.	T	
<i>Macrodon japeticum</i> , Forbes	.	.	.	Ariyalūr, Kara padi	.	A	
<i>Trigonoarca gaidrina</i> , Orb.	.	.	.	Serdamangalam, Shillagudi	.	A	
" <i>gamana</i> , Forbes	.	.	.				
" <i>abrupta</i> , Forbes	.	.	.				
" <i>brahminica</i> , Forbes.	.	.	.				
<i>Anomalocardia clevelandi</i> , Forbes	.	.	.				
" <i>pondiceriana</i> , Orb.	.	.	.				

NAME.	PONDICHERRI DISTRICT.			TRICHINOPOLI DISTRICT.		Foreign localities.	Age.
	Valudayur beds.	Trigonarca beds.	Nerinea beds.	Locality.	Stage.		
<i>Modiola polygona</i> , Forbes . . .	x	..	..		...	Allied to <i>M. flagellifera</i> , Zittel (non Forb.); Gosau.	Senon.
" <i>flagellifera</i> , Forbes . . .	x	..	..	. . . . .	...		
" <i>nitens</i> , Forbes . . .	?	..	..	Olapadi	A		
" <i>cypris</i> , Forbes . . .	?	..	..	= <i>M. typica</i> ? Forb. (Serdamangalam).	T		
<i>Pinna arata</i> , Forbes . . .	x	..	..	Anapadi	T	Europe Europe	Upp. cret. Upp. cret.
" <i>consobrina</i> , Orb. . .	?	..	..	. . . . .	A(U?)		
" <i>laticostata</i> , Stol. . .	x	..	..	Comarapalaia, etc.	A(U?)		
" <i>complanata</i> , Stol. . .	?	..	..	Anapadi, etc.	T		
<i>Avicula nitida</i> , Forbes . . .	x	..	..	Comarapalaia	A	Europe Europe	Upp. cret. Upp. cret.
<i>Gervillia solenoides</i> ?, DeFr. . .	?	..	..	. . . . .	...		
<i>Yamira quinquecostata</i> , Sow. . .	?	..	..	div. loc.	A, T, U	Borneo, Europe	Senon
<i>Plicatula septemcostata</i> , Forbes . .	?	x	..	. . . . .	A, T, U		
<i>Spondylus calcaratus</i> , Forbes . .	..	x	..	Serdamangalam	T	Europe Europe	Upp. cret. Upp. cret.
" <i>ariyalurensis</i> , Stol. . .	..	x	..	Mallur	A		
" <i>lamellosus</i> , Koss. . .	..	x	..		A	Borneo, Europe	Senon
<i>Exogyra ostracina</i> , Lam. . .	x	x	..	Ariyalur, Mallur	A		
<i>Ostrea</i> sp.	..	..	x		A	Europe, S. Africa, Madagascar, etc.	Senon.
<i>Alectryonia unguolata</i> , Lam. . .	x	x	..	Otacod	A		

<i>Anomia</i> sp.	x																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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EXPLANATION OF PLATES.

PLATE VI.

- Fig. 1.*—*Pachydiscus gollevillensis*, Orb.—*a*, side view; *b*, back view; *c*, sutures from the same specimen; $\frac{1}{4}$ mile W. of Rautankupam, Trigonarca beds.
- Fig. 2.*—*Pachydiscus ganesa*, Forbes.—*a*, side view; *b*, front view; *c*, sutures from the same specimen; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 3.*—*Pachydiscus* sp. aff. *gollevillensis*, Orb.—*a*, side view; *b*, front view, enlarged $\frac{2}{1}$; *c*, sutures from the same specimen; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 4.*—*Baculites vagina*, Forbes.—*a*, side view; *b*, ventral view; *c*, section from the same specimen; Rayapudupakam, Trigonarca beds.
- Fig. 5.*—*Nautilus tamulicus*, sp. nov.—Back view of a septum; Kadaperikupam?, Nerinea beds.
- Fig. 6.*—*Nautilus tamulicus*; sp. nov.—Section; Saidarampet, Nerinea beds.
- Fig. 7.*—*Belemnites* sp. (= *Belemnites fibula*, Forbes).—*a*, side view; *b*, section; $\frac{1}{4}$ mile N. N. W. of Rautankupam, Trigonarca beds.
- Fig. 8.*—*Pugnellus uncatus*, Forbes.—Back view of a cast; $\frac{1}{4}$ mile W. of Rautankupam, Trigonarca beds.

PLATE VII.

- Fig. 1.*—*Nautilus tamulicus*, sp. nov.—Side view; Saidarampet, Nerinea beds.
- Fig. 2.*—*Volutilithes muricata*, Forbes.—Front view; $\frac{1}{4}$ mile W. of Rautankupam, Trigonarca beds.
- Fig. 3.*—*Gosavia indica*, Stoliczka.—*a*, front view; *b*, back view; $\frac{1}{2}$ mile N. N. E. of Rautankupam, Valudayur beds.
- Fig. 4.*—*Euptycha larvata*, Stoliczka.—*a*, front view; *b*, back view; Rayapudupakam, Trigonarca beds.
- Fig. 5.*—*Cerithium karasurense*, sp. nov.—*a*, front view; *b*, back view of the last whorl; Karasur, Trigonarca beds.
- Fig. 6.*—*Cerithium* cf. *karasurense*, sp. nov.—*a*, back view; *b*, section of another specimen; Saidarampet, Nerinea beds.
- Fig. 7.*—*Nerinea* sp.—Section of a whorl; $1\frac{1}{4}$ mile S. S. E. of Valudayur, Nerinea beds.

PLATE VIII.

- Fig. 1.*—*Nerinea* sp.—Front view, natural size; $1\frac{1}{4}$ mile S. S. E. of Valudayur, Nerinea beds.
- Fig. 2.*—*Trichatropis* aff. *konnicki*, Müller.—*a*, back view; *b*, front view; $\frac{1}{2}$ mile W. S. W. of Tutipet, Trigonarca beds.
- Fig. 3.*—*Turritella warthi*, sp. nov.—*a*, back view enlarged; *b*, fragment from the same locality; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 4.*—*Trochus arcotensis*, Forbes.—*a*, top; *b*, basal; *c*, side view; N. N. W. of Tutipet, Valudayur beds.

- Fig. 5.*—*Teinostoma cretaceum*, Orb.—*a*, top ; *b*, basal ; *c*, side view ; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 6.*—*Bullina cretacea*, Orb.—*a*, front view ; *b*, back view ; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 7.*—*Bullina* sp.—*a*, front view ; *b*, back view ; 1 mile N. N. W. of Tutipet Valudayur beds.
- Fig. 8.*—*Dentalium crassulum*, Stol.—*a*, side view ; *b*, section ; 1 mile N. N. W. of Tutipet, Valudayur beds.
- Fig. 9.*—*Pholadomya lucerna*, Forbes.—Side view ; $\frac{1}{2}$ mile W. S. W. of Tutipet, Trigonoarca beds.
- Fig. 10.*—*Pholadomya lucerna*, Forbes.—*a*, side view ; *b*, umbonal view ; 1 mile S. S. E. of Pulichapalaam, lower Valudayur beds.

PLATE IX.

- Fig. 1.*—*Trigonoarca galdrina*, Orb.—*a*, side view ; *b*, inner view ; 1 mile N. N. W. of Tutipet, Valudayur beds.
- Fig. 2.*—*Trigonoarca galdrina*, Orb.—Side view ; $\frac{1}{4}$ mile W. S. W. of Tutipet, Trigonoarca beds.
- Fig. 3.*—*Trigonoarca galdrina*, Orb.—*a*, side view ; *b*, inner view ; 1 mile N. of Saidarampet, Trigonoarca beds.
- Fig. 4.*—*Siliqua limata*, Stol.—Side view ; 1 mile E. S. E. of Pulichapalam, lower Valudayur beds.
- Fig. 5.*—*Siliqua limata*, Stol.—Side view ; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 6.*—*Hippagus æmilianus*, Stol.—*a*, side view ; *b*, front view of a cast ; $\frac{1}{4}$ mile W. of Rautankupam, Trigonoarca beds.
- Fig. 7.*—*Baroda elicita*, Stol.—Side view ; 1 mile E. S. E. of Pulichapalaam, lower Valudayur beds.
- Fig. 8.*—*Pharcella delicatula*, Stol.—Side view ; $\frac{3}{4}$ miles S. E. of Wottai, Valudayur beds.
- Fig. 9.*—*Cyprina cristata*, Stol.—Side view ; $\frac{1}{4}$ mile W. of Rautankupam, Trigonoarca beds.
- Fig. 10.*—*Spondylus lamellosus*, sp. nov.—*a*, side view ; *b*, back view ; Saidarampet ?, Trigonoarca beds.
- Fig. 11.*—*Corbula parsura*, Stol.—*a*, side view ; *b*, umbonal view ; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 12.*—*Tellina forbesiana*, sp. nov.—*a*, side view ; *b*, umbonal region, enlarged ; *c*, umbonal view ; 1 mile N. N. W. of Tutipet, Valudayur beds.
- Fig. 13.*—*Tellina pondicherrensis*, Forbes.—Side view ; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.
- Fig. 14.*—*Tellina pondicherrensis*, Forbes.—*a*, side view ; *b*, umbonal view ; $\frac{1}{2}$ mile N. of Tutipet, Valudayur beds.

PLATE X.

- Fig. 1.*—*Plicatula septemcostata*, Forbes.—*a*, lower valve ; *b*, upper valve ; $\frac{1}{2}$ mile W. S. W. of Tutipet, Trigonoarca beds.

- Fig. 2.*—*Spondylus ariyalurensis*, Stol.—*a*, side view; *b*, back view; $\frac{1}{2}$ mile W. S. W. of Tutipet, Trigonoarca beds.
- Fig. 3.*—*Terebratula biplicata*, Sow.—*a, b, c*, different views; $\frac{1}{4}$ mile W. of Rautankupam, Trigonoarca beds.
- Fig. 4.*—*Terebratula arabilis*, Forbes.—*a, b, c, d*, different views; *e*, part of the test enlarged; *f*, section through the test enlarged; $\frac{1}{4}$ mile W. of Rautankupam, Trigonoarca beds.
- Fig. 5.*—*Hemiaster tamulicus*, n. sp.—*a, b, c, d*, four views of a perfect specimen natural size; $\frac{1}{4}$ mile W. of Rautankupam, Trigonoarca beds.
- Fig. 6.*—*Hemiaster pullus*, Stol.—*a, b, c, d*, four views of a perfect specimen; $\frac{1}{4}$ mile W. of Rautankupam, Trigonoarca beds.
- Fig. 7.*—*Scrpula filiformis*, Sow.—Natural size; $\frac{1}{2}$ mile N. W. of Tutipet, Valudayur beds.
- Fig. 8.*—*Orbitoides* sp.—Vertical (median) section; Saidarampet, Nerinea beds.
- Fig. 9.*—*Orbitoides* sp.—Vertical section; $1\frac{1}{4}$ mile S.S.E. of Valudayur, Nerinea beds.
- Fig. 10.*—*Orbitoides* sp.—Horizontal (median) section; $1\frac{1}{4}$ mile S. S. E. of Valudayur, Nerinea beds.
- Figs. 11, 12.*—*Amphistegina* sp.?—Vertical and horizontal section of different specimens; $1\frac{1}{4}$ mile S. S. E. of Valudayur, Nerinea beds.

Notes from the Geological Survey of India.

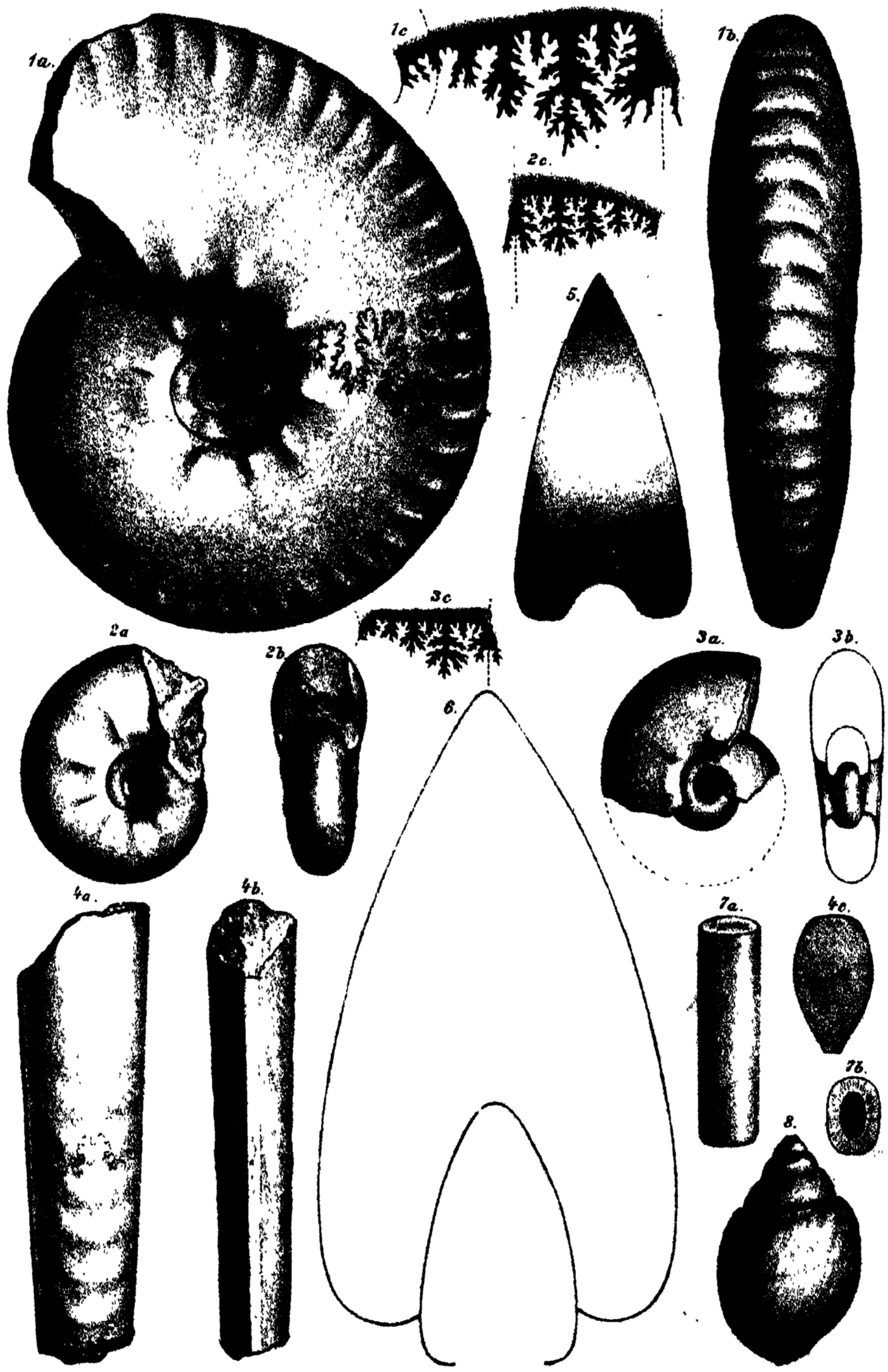
The occurrence of two minerals, previously unknown in India, may be recorded.

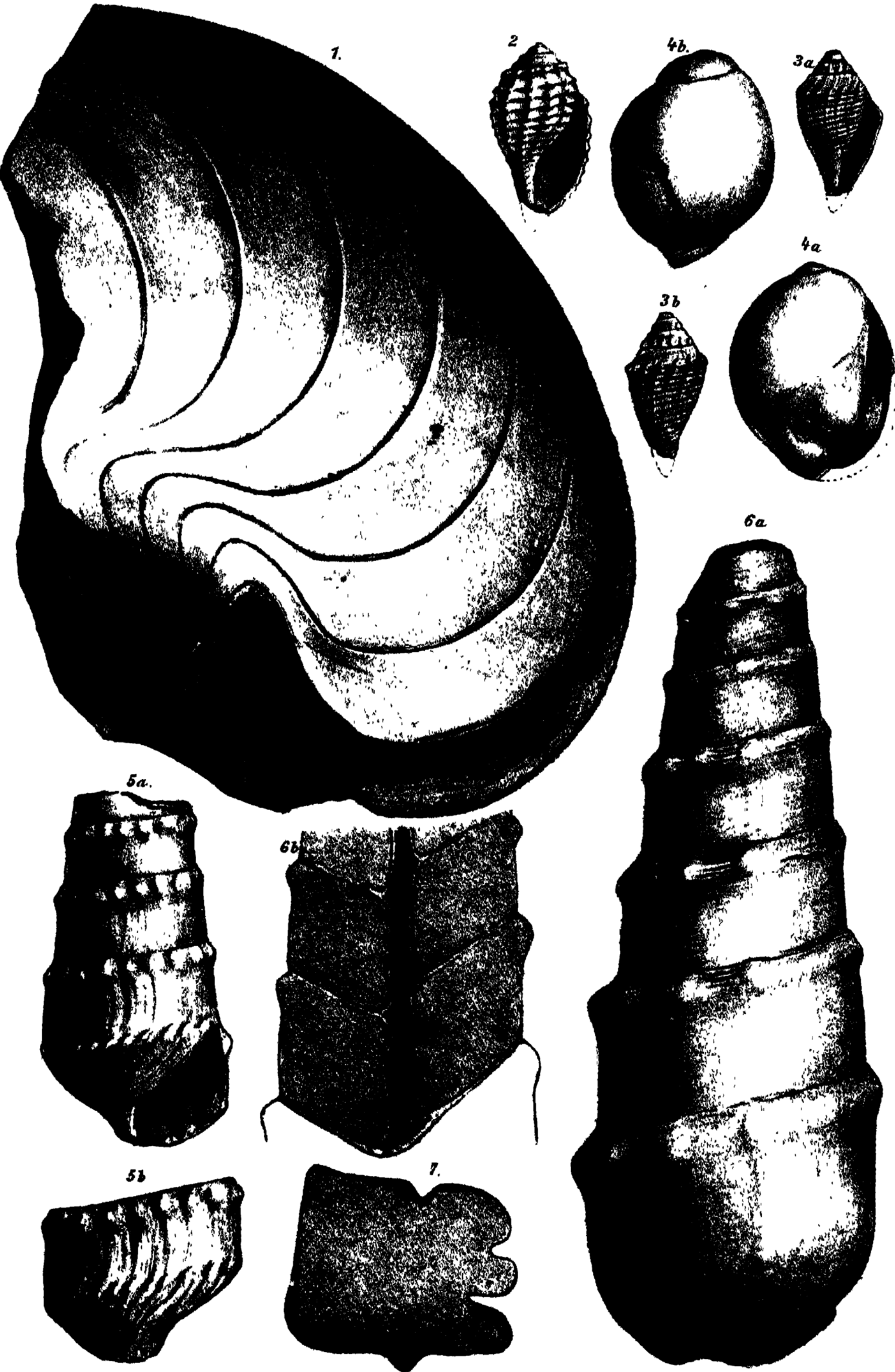
Aluminite from the Salt Range.—The first of these, aluminite, occurs in veins in the shale underlying the coal seam at Chittidand in the Salt Range and was collected by Dr. Warth in 1886. It has a chalky appearance, but under the microscope is seen to consist of small monoclinic crystals. The hardness is between degrees 1 and 2 of Moh's scale, and the sp. gr. is 1.707, being rather high on account of small quantities of admixed iron. A portion of the mineral, freed as much as possible from iron, was analysed by Mr. Hayden and found to have the following composition :—

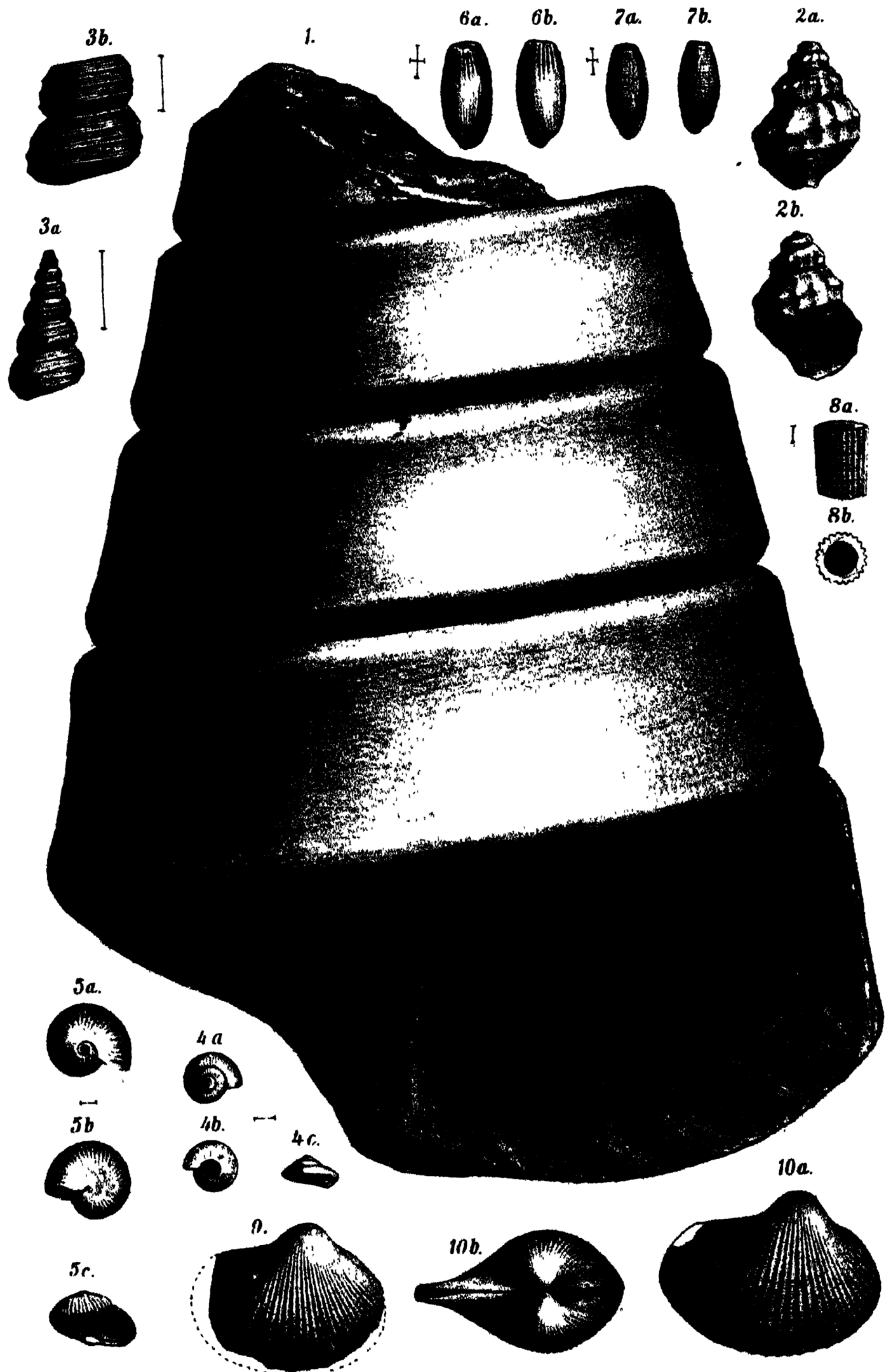
Al ₂ O ₃	.	.	.	.	.	.	.	30.08 per cent.
SO ₃	.	.	.	.	.	.	.	23.63 „
H ₂ O	.	.	.	.	.	.	.	46.44 „
Ca O	.	.	.	.	.	.	.	trace.
Zi O	.	.	.	.	.	.	.	„
Fe ₂ O ₃	.	.	.	.	.	.	.	„
								100.15

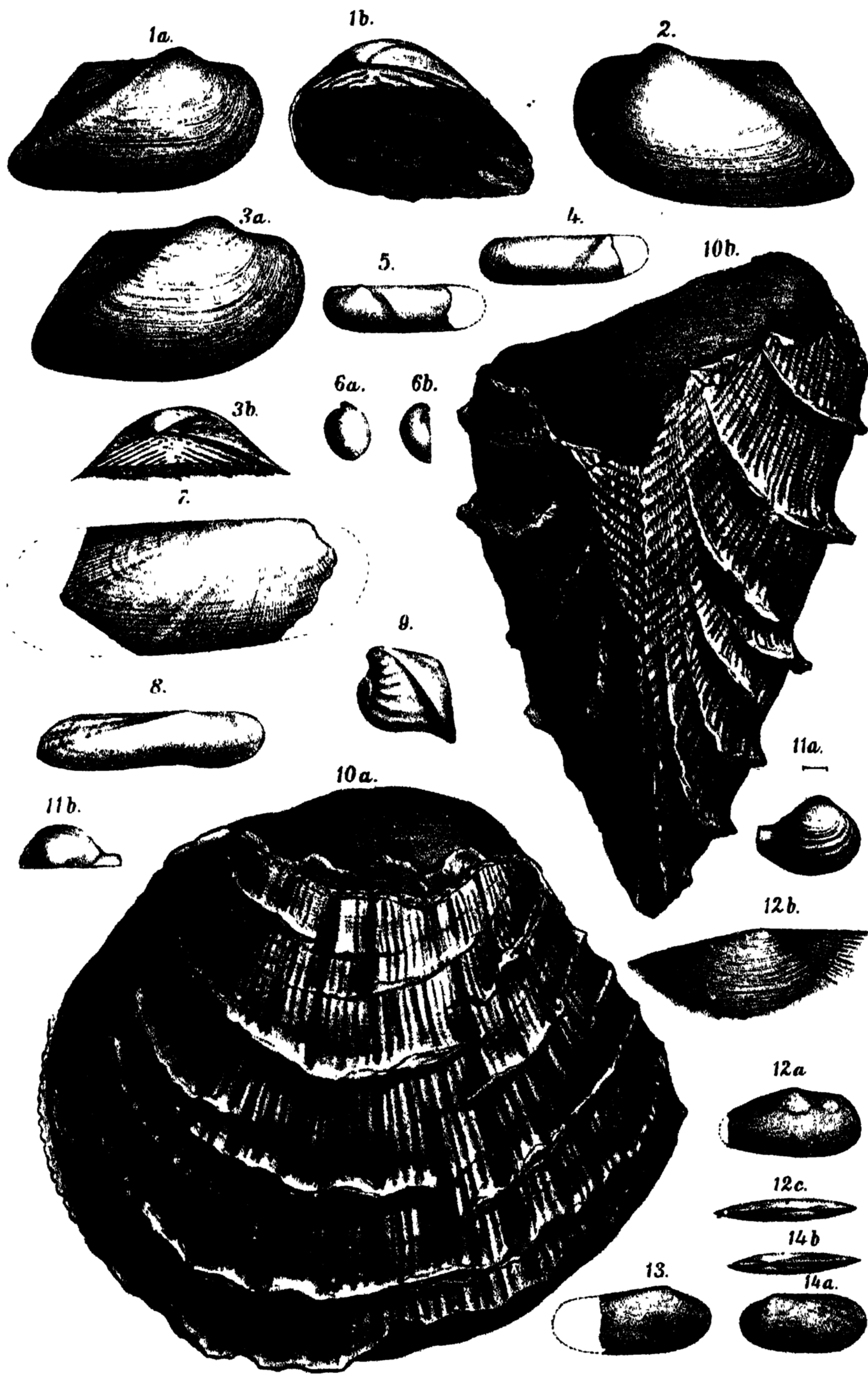
thus indicating the formula Al₂O₃, SO₃, 9H₂O.

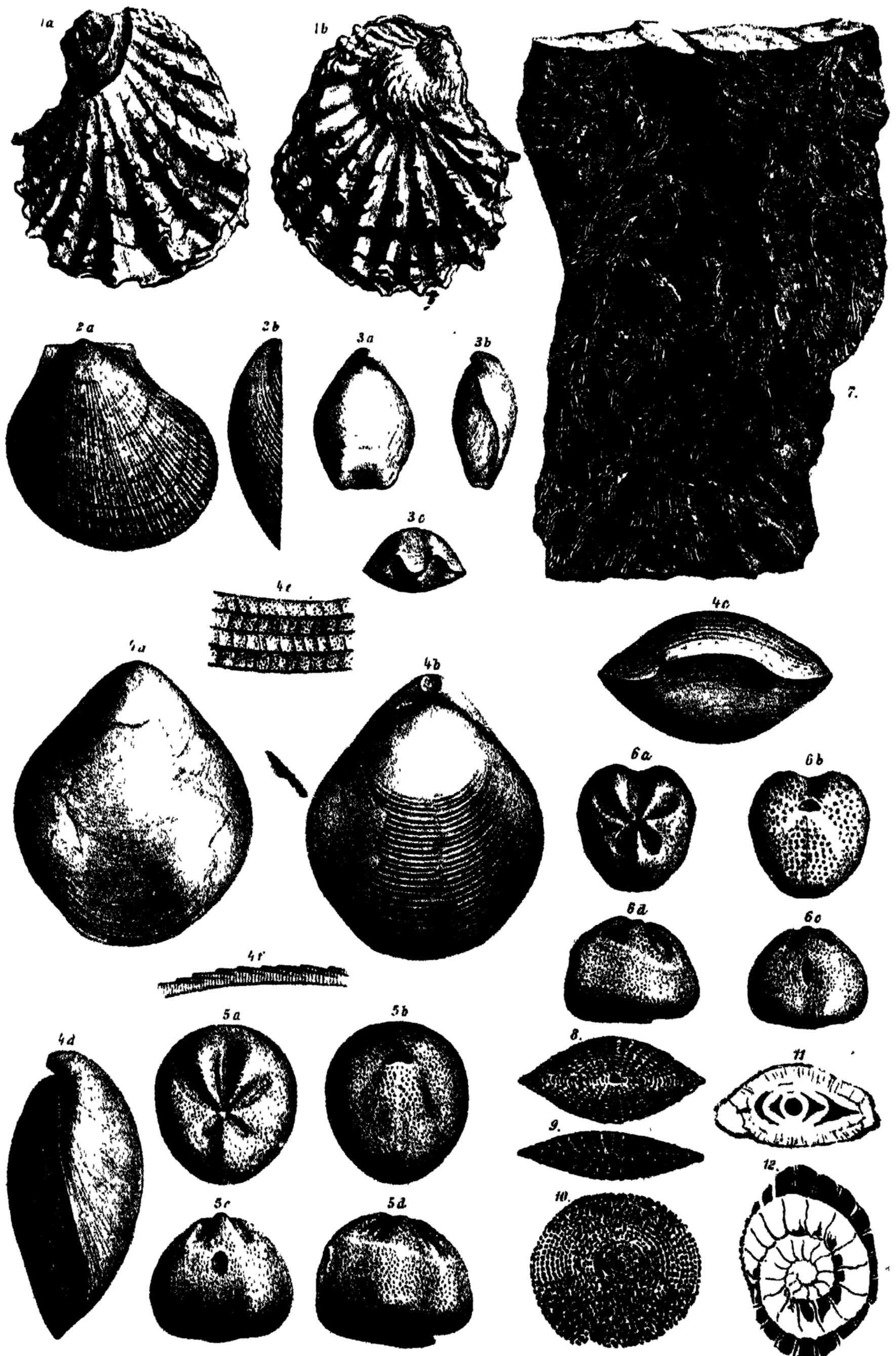
Altaite from Upper Burma.—The occurrence of altaite in the Choukpazat gold











mine, Wuntho, Upper Burma, is of greater interest, as it is the first recorded occurrence of a telluride in India. Found as small specks in quartz associated with free gold and auriferous pyrites, it was first identified by Professor H. Louis,¹ and an analysis subsequently made in the laboratory of the Geological Survey confirmed the identification.

Petroleum in Upper Burma.—The survey of the Yenangyat oilfield has shown that besides the exposure of pliocene beds, already being exploited, at Yenangyat there are two other exposures along the same anticlinal which may be regarded as future oilfields. One of these lies south of the Irawadi, to the south of Singu, in block 58N of the Yenangyoung oilfields survey. The other lies to the north of Yenangyat and extends from the north part of block 4 of the Yenangyat oilfields survey to about 6 miles north of the limit of this survey. This exposure is larger and beds of miocene age (Prome stage) crop out along the axis of the anticlinal, the first oil sand of the Yenangyat borings being exposed at the surface. At one place the hill is reported to have been on fire last year, the flames being about 3 feet high.

Mud-Volcano in Tipperah.—On 17th March some specimens of mud were received through the Director of Land Records and Agriculture, Bengal, from Mr. F. G. Cumming, Settlement Officer of Chakla Roshnabad, said to have been taken from "a place on the borders of the District of Tipperah, where there is at present a tiny volcanic eruption." In the same letter it is stated that the villagers said that "about thirty years ago there was a similar manifestation; and that a mound was made over the spot. All that is now visible is a flame about 6 inches high issuing from a hole in the centre of this mound, which is about five feet above the surrounding lands, which are rice fields but quite close to the frontier hills."

The dried mud sent with this letter was of the same type as that thrown out by the mud-volcanoes of Arracan and Minbu, and Mr. Cumming's account left no room for doubt that he had discovered a small mud-volcano or salse in a previously unrecorded locality. In reply to an enquiry for more precise information as to the site, Mr. Cumming reports that it is "in the centre of cultivated land at the foot of the Tipperah hills on the eastern boundary of Tipperah district, and 16 miles due north of the sadar station Comilla. The site of the little eruption is in a village called Ballabpur, and is, as far as I can calculate, in $91^{\circ} 15' 30''$ east longitude and $23^{\circ} 40' 30''$ north latitude. This village is not marked on the four miles to the inch district map of Tipperah, but the adjoining village Horepur is."

¹ Trans. Fed. Inst. Min. Eng., XII, 513, (1897).

DONATIONS TO THE MUSEUM.

FROM 1ST FEBRUARY TO 30TH APRIL 1897.

Three small pieces of a meteorite that fell at Nawapali, Sambalpur district, Central Provinces, on the 6th June 1890, at 6 P.M.

Sent by the Commissioner of Settlements and Agriculture, Central Provinces, Nagpur.

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FROM 1ST JANUARY TO 31ST MARCH 1897.

*Titles of Books.**Donors.*

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MAPS.

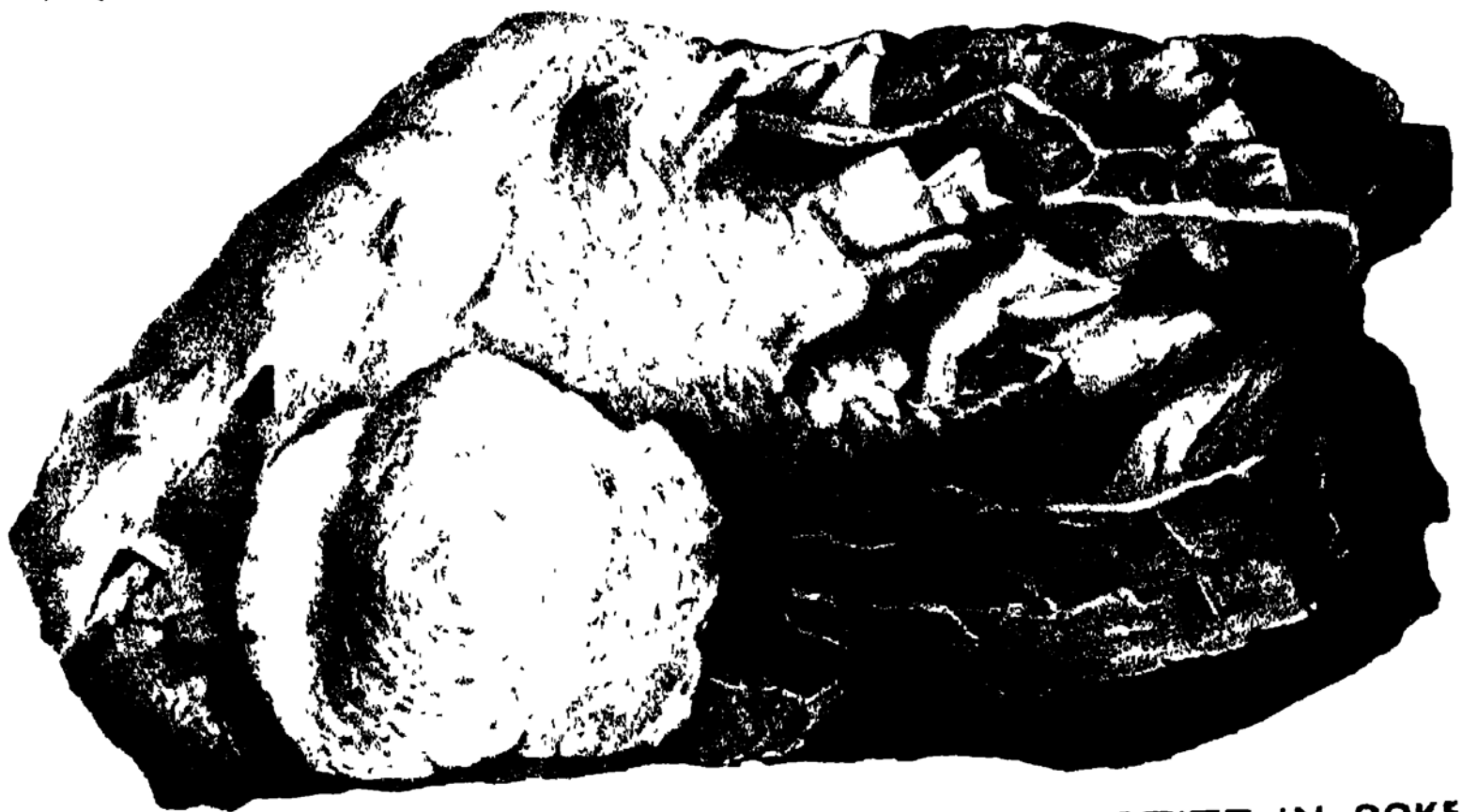
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THE GEOLOGICAL BUREAU.

1914-15



PIPE AND RAMIFYING VEINS OF MICA PERIDOTITE IN COKE.

² Natural Size



DYKE OF MICA PERIDOTITE WITH COLUMNAR COKE.

¹ Natural Size

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.

1897.

August.

Note on Flow-structure in an Igneous dyke, By THOMAS H. HOLLAND, A.R.C.S., F.G.S., Officiating Superintendent, Geological Survey of India (with plate XI).

Amongst the many striking proofs of the igneous nature of the dykes of "mica-trap" occurring so abundantly in the coalfields of Bengal, two specimens collected by Dr. Saise and myself in the Laikdih Colliery, near Barakar, and now preserved in the Geological Museum, Calcutta (Nos. 10-50 and 10-47), illustrate in an unusual and interesting manner the condition of the rock at the time of its intrusion.

The first specimen (No. 10-50) is a portion of a dyke with fringes of columnar coke on either side. The width of the dyke is only 8 inches, and, when found, the columnar coke extended 7 inches outwards on either side, passing into the normal coal of the bed through which the dyke was intruded. The rock is a variety of a mica-peridotite which, as I have shown in a previous note, is remarkable for the large amount of apatite it contains.¹ At the selvages of this narrow dyke the rock is seen to be perfectly compact, whilst towards the central portions the disposition of the biotite flakes in waves shows the direction in which the current was flowing just before the molten material consolidated, the viscous mass continuing to move slowly forward in the central portions of the dyke after the crystallization of much of the biotite and after the consolidation of the selvages (plate XI, fig. 1). The second specimen from the same locality (No. 10-47) shows a cross section of a pipe of mica-peridotite in coke only 2 inches in diameter, displaying the concentric arrangement of the mica flakes parallel to the edges of the circular hole through which the molten matter passed (plate XI, fig. 2).

Considering the number and size of the great intrusive sheets of this remarkable rock, and the narrowness of the dykes, which has been remarked in all the coalfields in which the rock occurs, veritable streams of molten material must have flowed along the narrow dyke fissures from below to form such extensive sheets as that which caps the coal seam at Laikdih. It is an interesting circumstance to find this inference so strikingly confirmed by such specimens of "fossilized" subterranean streams, which exhibit the usual character of streams, namely, greater freedom of movement in the centre.

I have, in the paper quoted,² referred to other evidences pointing to the high temperature and mobile condition in which this rock must have been at the time of

¹ *Rec. Geol. Surv. Ind.*, XXVII, 129 (1894).

² *Rec. Geol. Surv. Ind.*, XXVII.

its intrusion, and it naturally follows that such a mobile condition of intrusion is consistent with the narrowness of the dykes compared with the great extent of the sheets and laccolitic reservoirs which have been supplied with molten material through the narrow dyke fissures.

Additional note on the Olivine-norite dykes at Coonoor, Nilgiri Hills.
By THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India* (with plate XII).

I.—INTRODUCTION.

1. In a paper on the basic dykes of Southern India reference was made to the interesting variations in grain exhibited by the dykes near Coonoor.¹ Since the publication of that paper opportunity has occurred for examining with greater precision the general conclusions then stated with regard to the passage of the well crystallized types, in the larger dykes, into the forms with a vitreous matrix, at the selvages and in the thin veins which ramify amongst the "pyroxene-granulites" into which the trap dykes are intruded.

II.—GEOLOGICAL CHARACTERS.

2. The dykes which have been examined at Coonoor vary in thickness from ten feet to one tenth of an inch. The widest dykes are well exposed in the cutting made for the new ghát road to Mettapalaiyam, whilst a large number, varying from two feet in thickness to thin films, are beautifully displayed on the well washed masses of rock forming the bed of the Coonoor river, immediately below the bridge. The rocks into which the dykes have intruded are varieties of the peculiar hypersthene-bearing "pyroxene-granulites," which are such prominent constituents of the main mountain masses of the Madras Presidency. At Coonoor these rocks are well foliated and generally contain large quantities of blue quartz and garnet (Nos. 9'307, 10'669 and 11'362). They include bands of large lenticular masses of pyroxene-felspar rocks, generally with biotite (Nos. 9'302, 9'303 and 11'363), through which the dykes pass, as well as through the ordinary pyroxene-granulite in which these lenticles occur. The strike of the foliation of the pyroxene-granulites is east-north-east and west-south-west, whilst the dykes run north-north-west and south-south-east, or at right angles to the foliation planes. The foliation of the pyroxene-granulites was evidently completed before the intrusion of the dykes; but since the infilling of the fissures now occupied by the "traps," small movements have occurred along the same direction, as shown by the shearing of one of the narrow dykes. The phenomena of chilled selvages, such as are described below, show that the pyroxene-granulites had previously consolidated and were comparatively cold at the time of the intrusion of the trap.

¹ *Rec. Geol. Surv. Ind.*, XXX, 25 (1897).

GEOLOGICAL SURVEY OF INDIA.

T. H. Holland

Records, Vol: XXX. Plate XII.



Fig. 1
DYKE 10 FT. WIDE.

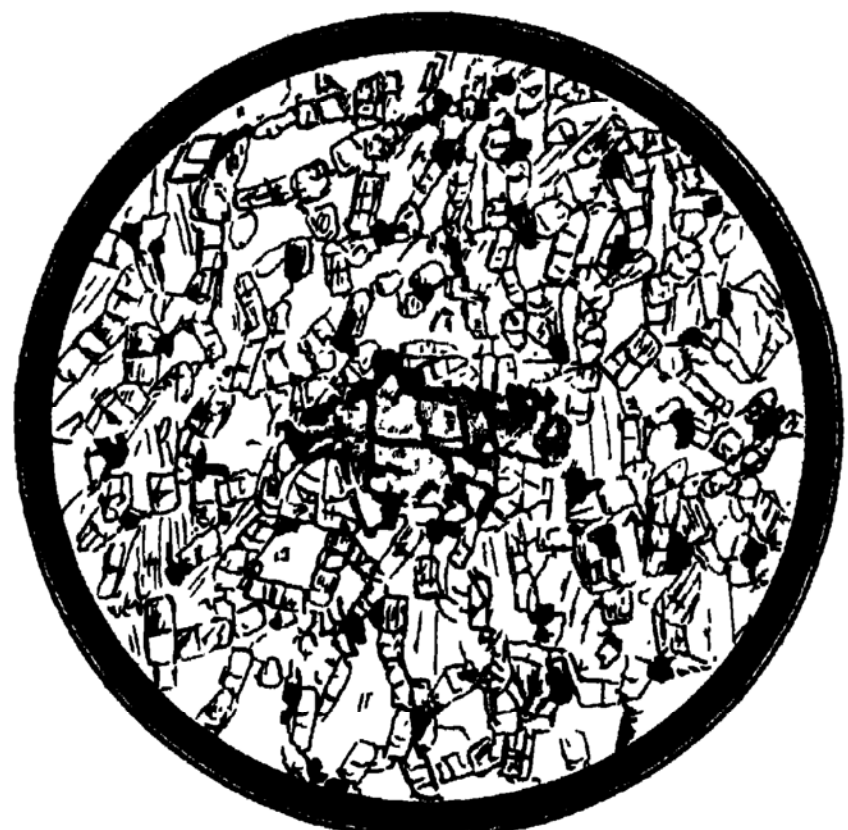


Fig. 2
DYKE 2 FT. WIDE.



Fig. 3
DYKE 4 INCHES WIDE.



Fig. 4
DYKE 1/2 INCH WIDE.

OLIVINE-NORITE DYKES AT COONOR,
NILGIRI HILLS.

Magnified 20 diameters

III.—PETROLOGICAL CHARACTERS.

3. The rocks, which show the variations in structure described below, belong, as stated in the paper already mentioned, to the group of olivine-norites, and exhibit invariably the following approximate order of consolidation of their essential constituents :—

- (1) Olivine and iron ores.
- (2) Enstatite.
- (3) Augite.
- (4) Plagioclase.

4. The *olivines* are remarkable for their smoky-brown colours when their inclusions are apparently of ultra-microscopic dimensions, and for their grey colour when the dusty inclusions are sufficiently large for individual recognition with the higher powers. These inclusions are arranged in parallel lines, and are almost certainly the representatives on a very minute scale of the dendritic inclusions recognised in members of this group collected in other parts of the Madras Presidency.¹ Another peculiarity, well-displayed by the olivines of the Coonoor dykes, is their ragged outline and enveloping zone of stumpy colourless enstatite crystals forming glomero-porphyrific groups. The irregular outline of each olivine is probably due to the fact that the crystallization of the enstatites commenced in its immediate precincts, before the complete crystallization of the former mineral.

5. In view of the known fact that a crystal exerts an influence on the magma in its immediate neighbourhood, the occurrence of these zones of enstatite round the olivines, forming glomero-porphyrific groups in the hemicrystalline varieties of the olivine-norites, is a feature of very great mineralogical interest. The "sphere," "court," or, to use an expressive Anglo Indian term, "compound," around a crystal (*der Hof des Krystalles*) can, as shown by O. Lehmann,² be strikingly illustrated experimentally in cobalt-chloride solutions. Crystals of hydrated cobalt chloride ($2\text{CoCl}_2 \cdot 12\text{H}_2\text{O}$) are rose-red in colour, whilst the anhydrous salt (CoCl_2) is blue. A solution of cobalt chloride at the ordinary temperature is rose-red in colour; but on warming, the colour changes to blue, presumably on account of the dissociation of the hydrate. The temperature at which this change takes place depends on the concentration of the solution; that is to say, the blue solution would become pink if the solution were diluted, without change of temperature. Now, when a crystal of cobalt chloride, growing in a blue solution, is watched under the microscope, it is seen to be surrounded by a pink zone, which is evidently due to the fact that the crystal, having drawn material from the zone immediately around it, has left that zone relatively more dilute than the rest of the solution, and the cobalt chloride remaining in that zone (that is, within the "court" of the crystal) exists in the more hydrated form.

The case of the olivine crystals growing in a basic magma is strictly analogous to that of the cobalt chloride. An olivine forms in a basic molten magma when the temperature is sufficiently reduced to allow of the formation of the "molecular compound" represented by the formula $2(\text{Fe}, \text{Mg}) \text{O} \cdot \text{SiO}_2$. The

¹ Cf. *loc. cit.*, p. 24.

² *Zeitschr. für Kryst.*, 1, 99.

removal of this basic molecular compound from the magma in the immediate vicinity of the growing olivine crystal must result in the production of a zone in which there is a relatively smaller quantity of the bases magnesia and iron, a more siliceous, more acid, or more dilute zone, and out of this more acid zone we have the higher silicate crystallized as a rim of enstatite crystals, whose composition is represented by the formula $2(\text{Fe}, \text{Mg})\text{O} \cdot 2\text{SiO}_2$; that is, a molecular compound containing twice as much silica as the olivine. The relation which the olivine bears to the enstatite is therefore precisely similar to that which the blue crystals of cobalt chloride bear to the pink, more hydrated, form which exists in the surrounding zones, or "courts," of the crystals.

6. The *iron ores* form a considerable proportion of the rocks. Besides the magnetite and titaniferous ore, a considerable proportion of the iron exists as pyrites. In the coarser grained rocks they form distinct granules with cubic outlines (11'350 and 11'351), which are noticeably smaller in the narrower dykes (11'356 and 11'353), existing as mere dust near the selvages of veins up to 3 or 4 inches in thickness (11'352) and occurring in particles of ultra-microscopic dimensions, diminishing the translucency of the glassy matrix of the minutest veins (11'352). In the last mentioned varieties of the rock the removal of the dust from the matrix immediately surrounding a crystal of magnetite, showing a narrow "court" of clear glass, is occasionally exhibited.

7. In addition to its existence as a "courtier" to the olivine, *enstatite* forms isolated well shaped crystals, scattered through the rock. It frequently exhibits a very faint pleochroism—the pleochroism characteristic of rhombic pyroxenes—and sometimes forms long crystals which can be easily recognised by the naked eye in the finer grained selvage of the larger dykes and in the narrow veins (11'353). The shapes, cleavage and optical characters agree with those of a rhombic pyroxene containing a comparatively low percentage of iron, and call for no further remark.

8. *Augite* is far less abundant than the rhombic pyroxene, which is in agreement with previous observations concerning the rocks of this class.¹ No other feature worthy of special remark has been noticed in connection with this constituent.

9. The *plagioclase* crystals, both in the glassy varieties and in those with a microcrystalline matrix, often show inlets filled with the magma. Whether these are the result of corrosion by the magma, or whether they are due to the inclusion of portions of the magma by irregularities in the growth of the felspar, is not certain. As plagioclase is the latest of the constituents to crystallize, it is more probable that the magma would be in a more viscous condition than when the ferro-magnesian silicates were separated; the increased viscosity would consequently interfere with freedom of development during the formation of the outer (younger) layers of plagioclase in each crystal, and as a result irregularity of outline would probably result. This circumstance, together with the fact that the portions of the magma protruding into the plagioclase-crystals, both in the glassy and in the microcrystalline varieties of the rock, are precisely similar in character to the general matrix, may be regarded as evidences

¹ Cf. *Ree Geol. Surv. Ind.*, XXX, 22.

against the theory of corrosion, although the inlets in general shape and appearance are at first sight remarkably similar to the cases of presumably corroded quartz-crystals so common in rhyolites. Crystals of enstatite are very frequently found included by plagioclase.



Fig. 1. Plagioclase (P) with inlets filled with basic glass. E. E. Crystals of enstatite.

In a thin vein ($\frac{1}{10}$ in.) of glassy enstatite-basalt (olivine-norite glass). Coonoor. $\times 35$.



Fig. 2. Plagioclase crystal (P) with inlets of the pilotaxitic matrix. From olivine-norite dyke 3 inches wide. Coonoor. $\times 80$.

IV.—VARIATIONS IN STRUCTURE.

10. The variation in size of grain is strikingly shown by a comparison of sections taken from the centres of dykes varying in width from 10 feet down to $\frac{1}{10}$ inch. In a dyke 10 feet wide the felspars attain a length of 0.025 inch (Plate XII, fig. 1). A section taken from a dyke 2 feet thick shows the rock to be very fine-grained (fig. 2), whilst in a dyke only 4 inches thick the groundmass is quite pilotaxitic (fig. 3), and in a branch from this dyke, only one tenth of an inch thick, the phenocrysts of olivine, pyroxene and plagioclase are seen lying in a brown, glassy matrix (fig. 4). It is interesting to note that the zone of enstatite forming the olivine crystal "court" becomes more marked in the finer grained varieties; in the wide dykes the crystals of the groundmass are not much smaller than those of early formation; that is, the rock is more distinctly porphyritic in the narrower dykes which cooled more rapidly than the larger masses. In the plate (fig. 4) the junction of the glassy variety of the olivine norite with the pyroxene granulite into which it is intruded is shown in the left-hand lower part of the field. The olivines of this thin vein have been altered to green serpentine, but in all the other specimens they are absolutely fresh.

Report on some trial excavations for Corundum near Palakod, Salem District, by C. S. MIDDLEMISS, B.A., Geological Survey of India (with plate XIII).

INTRODUCTION.

1. My preliminary reports¹ on the corundum-bearing beds in the Salem and Coimbatore Districts having shown that a practical trial as to the richness and value of the deposits was advisable, it was decided, after consultation with the Government of Madras, that the executive part of the work should be carried out by the Public Works Department under the supervision of the Subdivisional Officer of the Public Works Department for the Tirupatur Circle, whilst the sites to be tested and the general conduct of the operations should be superintended by myself, with the help of a native assistant geologist, Mr. S. Sethurama Rau, B.A., who would personally and continuously watch the operations and carry out instructions furnished by me.

2. I chose first a site in some waste land near the village of Erranahalli, and about $2\frac{1}{2}$ miles south-west-by-south of Palakod, the nearest large town. The position was one among a number of outcrops of the corundum-bearing band, now known as the Paparappatti band. This will in future be referred to as No. 1 working. As soon as the necessary formalities had been complied with and the preparations completed, experiments were started in November 1896 and continued until 15th March 1897.

3. Before going any further, it will be well to state what was already known concerning these corundum occurrences. On my first visiting them in 1894, the only information then available was that corundum occurred near Pennagaram in the Dharmapuri taluq, as shown by the presence of specimens in the Madras Museum, thus labelled, sent by the local authorities. Since then details were from time to time gathered by my survey, so that up to the time of the opening of the pits at working No. 1, the information stood as follows:—

- (a) The actual matrix of the corundum in this band was known to be in the form of lenticles in a gneiss, among which biotite was prominent as the dark mineral. Such of these lenticles as had actually been seen *in situ* were, however, small, the largest being 3 feet by 1 foot.
- (b) That larger lenticles occurred in the alluvium covered plain near Paparappatti and on the hillsides to the west, was however inferred from large blocks having been found in the surface debris.
- (c) It was known from the presence of old shallow trenches and pits in the alluvium and surface rock that corundum had been dug at some previous time from this neighbourhood. Local information and the exposure of corundum for sale in the surrounding market towns, also made it certain that corundum was at that time being occasionally gathered.
- (d) It was also evident that, in a general way, the strike of the rock bands containing the corundum was with the strike of the country, namely,

¹ Reports to the Government of Madras, the first of which was reprinted with slight alterations in *Records, G. S., I., Vol. XXIX, pt. 2, 1896, pp. 43—46.*

about north by east, and it was supposed from the slightly different character of some of the corundum occurrences and also from their position that more than one parallel band of the rock existed.

- (e) The position of all the corundum occurrences was as indicated on the accompanying plan, from which it will be seen that the Paparappatti band extends (but with some notable gaps) from Donnakuttahalli near the Cauvery river to Chintalakuttai village near Rayakottai, a distance of nearly 40 miles.

4. The general object of the practical work which I was now endeavouring to carry out was, as stated in the Annual Report of the Geological Survey for 1896, namely,—“The excavations, or quarries as they will be, are intended to show the thickness of the corundum-bearing bands, and whether they are continuous or occur as lenticular patches. A fair average sample of the rock extracted, of sufficient size to give a trustworthy estimate of the richness of the rock, is to be carefully cleaned by hand, and the proportion of corundum to matrix determined by weighing.”

5. The nature of the work resolved itself into :—

- (a) Preliminary clearing of the ground of jungle.
- (b) Digging of trenches until the corundum-bearing rock was exposed.
- (c) Blasting and quarrying the matrix-rock.
- (d) Breaking up the lumps with wedges and hammers into sizes suitable for demolition by hand.
- (e) Cleaning the corundum by hand and weighing.
- (f) Excavations to show continuity or otherwise of the rock matrix.

GEOLOGICAL DETAILS.

6. A brief outline only will here be given regarding the petrology of the neighbourhood of the workings, inasmuch as many details still require working out. I may mention, however, in particular that in addition to biotite in the fundamental rock in which the lenticles occur there is at this place much hypersthene also present, which together with felspar, quartz and iron ores makes up a biotite-hypersthene granulitic gneiss, and which is therefore mineralogically a passage between the ordinary charnockite series and the Hosur biotite gneiss. It is finely, and not very distinctly foliated, the strike being generally between north and south and north-north-east and south-south-west. The dip of the foliation planes is generally steep, approaching the vertical in most available sections, but the amount and nature of the folds indicated by such dips are never definite enough to allow of a sectional representation of them.

7. Occurring sparingly as adventitious veins and veinlets in this gneissic rock and palpably younger in age than it, come a coarse flesh-pink and white, rather coarse pegmatite, and some trap dykes. These veins and dykes, though sometimes following the foliation, also occur completely irregularly. Some of the gneiss also presents the character which has been called “trap-shotten,” a feature peculiar in itself and too complicated to be described in this note.

8. The actual matrix of the corundum in the workings was found, as anticipated from my previous observations, to be in the form of lenticles in the gneissic rock. These lenticles are symmetrically shaped and are easily recognised by their exter-

nal shell of rock very rich in biotite, and by the paler coloured central parts which are less rich in ferro-magnesian minerals. The exact mineralogical composition of these lenticles is still under investigation, and both it and the origin of the lenticles offer problems whose solution will not be attempted here. In size the lenticles vary from the very small ones referred to in my previous report up to such as the one broken up at No. 1 working, which measured 13 feet long, by 8 feet broad and 9 feet deep; the shape being that of an ellipsoid with three unequal axes. A plan showing the excavations at No. 1 working and in the vicinity (see Plate XIII) will sufficiently make clear the disposition, shape and size of the three lenticles which have so far been exposed in the course of the work, and will indicate the degree of probability attaching to the statement, which I think is a correct one, that these lenticles are really dispersed in a bed, layer, or plane, and that therefore they have the same general continuity as any other rock-band. In support of this it may be mentioned that half a mile west-south-west of Gollahalli subsequent trial trenches exposed a large lenticle, along the same line of strike, and identical in composition with the three already referred to. This lenticle on partial exposure measured 15 feet long by 8 feet broad.

As these lenticles were originally only indicated at the surface of the ground by the presence of fragments of corundum and matrix rock and by old shallow excavations, and as prospecting in the neighbourhood has revealed a great number of similar indications (roughly represented by the crosses on the map), it seems to me only reasonable to conclude that a detailed examination of the neighbourhood foot by foot, and a judicious series of cross trenches would expose more lenticles of the same kind along the present line or along other parallel lines. At the present moment there must be about 20 tons of matrix left at working No. 1, and about as much in the third lenticle, whilst the Gollahalli lenticle will probably yield 60 tons or more; so that about 100 tons of matrix-rock are now ready to hand.

9. The corundum in the matrix-rock occurs in well shaped crystals which in this particular locality are of a dark purplish-grey colour. As described in my previous paper, they are surrounded by a pale pink shell of orthoclase from which they break out sharp and clean like a kernel from its shell. Their forms are elongated barrel-shaped combinations of the hexagonal prism and pyramid. The size of the crystals varies considerably, but may be said to be definitely limited in the following way. The largest crystal found in the broken-up lenticle was 7 inches $\times$ 2 inches, whilst the smallest sizes of which any account need be taken are $\frac{1}{2}$ inch $\times$ $\frac{1}{4}$ inch. An average size for the crystals in this lenticle, I should estimate at 2 inches $\times$ $\frac{3}{4}$ inch.

The corundum seems to be quite pure throughout the lenticle, but in the course of the excavation, Mr. Sethurama Rau found that a layer of the outer disintegrated rock near the upper side of the lenticle yielded a number of dark nearly black lumps or nodules of hercynite mixed with corundum. Sometimes a central core of corundum was surrounded by a shell of hercynite. The latter is in a crystalline-granular state, and has probably grown in a concretionary way round pieces of corundum as nuclei. Unfortunately none of these concretions were found actually in solid rock, but inasmuch as none are present in the main mass of the lenticle, it is probable that they came from the outer crust of it where ferro-magnesian minerals are more thickly grouped.

PROPORTION OF CORUNDUM IN THE ROCK.

10. One of the chief objects, or rather *the* chief object, of the practical investigation of these rocks, was to determine by careful weighings the proportion of corundum in the matrix-rock. To attain this end, the broken-up rock was weighed as it was given out to the coolies, and the resulting corundum was collected at the end of each day and also weighed. This was done every day and a regular account kept.

The total results as given me by Mr. T. Ramanujam Pillay, Subdivisional Officer, Public Works Department, in charge of the work are :—

722 cwts. of matrix-rock yielded 2,845lb of corundum,
or 3·5 per cent. nearly.

This total is considerably lower than the percentage obtained from the weighing of the first ton of matrix, which gave, as quoted in the Annual Report :—

1 ton of matrix-rock yielded 150lb of corundum,
or 6·7 per cent. nearly.

From enquiry, and a study of the daily returns of the weighings, the difference seems to be accounted for in the following two ways. In the first place, when the original big lenticle was blasted, a great many of the larger crystals of corundum broke away and fell out, and they were straightway included in the first weighings. Secondly, all parts of the lenticle were not equally rich, and the richer parts appear to have been selected first. As a third reason it is possible that a certain amount of pilfering may have taken place from the exposed heaps of matrix-rock as time went on. It seems safest to take the total percentage on the whole work as giving probably the nearest approach to a true average, because so long as hand-work alone is used in cleaning the corundum, if loss occurs either by pilfering or carelessness, such would also be likely to occur in actual mining operations.

COST OF THE OPERATIONS.

11. Although a small experiment carried on as this one has been is likely to be more expensive than one worked on a larger scale as a paying concern, yet I give below the actual costs as offering some evidence under this head.

The figures given first below apply to the work done to the first two lenticles of matrix-rock at working No. 1, which supplied all the rock broken up and weighed. These figures also were furnished me by the Subdivisional Officer :—

	R	a.	p.
Clearing ground of jungle, about	20	0	0
Earthwork at the quarry, digging trenches, etc.	71	5	0
Blasting	11	9	0
Breaking matrix-rock and sorting 722 cwts. @ Ro-2-6 per cwt.	112	6	0
Cleaning the above @ Ro-2-6 per cwt.	112	6	0
Sundries—boxes, bags, cartage	35	0	0
Erection of sheds for workmen	22	8	0
TOTAL	385	2	0

or Ro-8-7 per cwt. of broken rock,
i.e., Ro-8-7 per 3·9lb of cleaned corundum.

Further, it was found that $1\frac{1}{2}$ men at $3\frac{1}{2}$ annas were able to break 1 cwt. of matrix-rock and clean corundum from it.

12. The cost of making other excavations, exposing other lenticles, trial trenches here and at Gollahalli and near Paparappatti was Rs 354.

13. From the figures given in paragraph 11, it will be seen that the two items of greatest expense are those for breaking out and cleaning the corundum by hand, namely (Rs 112-6-0) $\times$ 2. It is clear, therefore, that if the extraction of corundum is attempted on a large scale, the adoption of machinery for crushing and washing the corundum, as a substitute for hand-work, would be a desideratum.

FURTHER EXPERIMENTS CONTEMPLATED.

14. Work for the present had to be closed on 15th March. Meanwhile samples of the corundum and matrix will be sent to firms in India and England for testing and valuation. Should their reports be favourable, and the percentage of mineral to matrix deemed not prohibitive, I shall hope to make further trial excavations at other places along the Paparappatti band of outcrops.

Report on the occurrence of Coal at Palana Village in Bikanir State By TOM D. LATOUCHE, B.A., *Superintendent, Geological Survey of India* (with plate XIV).

During the latter part of the year 1896, while sinking a well at the village of Palana in the State of Bikanir, a seam of coal was passed through at depth of 212 feet from the surface. A small sample of the coal was sent to the Geological Survey Office in Calcutta by Lieutenant-Colonel Vincent, Political Agent in Bikanir, for analysis, and the result, as given below, indicating that the coal was of fairly good quality, and would be of great value as fuel if it existed in any quantity, especially in a country so devoid of forests, where every ounce of coal for the railway has to be imported from a great distance and at enormous cost, it became of the highest importance to determine what steps should be taken to discover the extent of the seam. I was accordingly instructed to visit Palana before closing work for the season and report on this discovery.

The village of Palana is situated in N. Lat. $27^{\circ} 51'$ and E. Long. $73^{\circ} 18'$, about 13 miles to the south of the city of Bikanir. The country for several miles in every direction surrounding the village is entirely covered with blown sand and alluvium, no solid rock being anywhere visible at the surface. It is therefore only from the evidence afforded by wells that any information can be obtained about the rocks concealed beneath the surface. And not much can be learnt from the older wells, as their sides are covered with a hard cement to keep them from falling in. This new well at Palana was however sunk under efficient European supervision, and a record was kept of the strata passed through. I am indebted to Mr. J. E. Gabbett, Executive Engineer, Public Works Department,

the State Engineer, and to his Sub-Overseer Gunga Bishen, a most intelligent man, for the information embodied in the vertical section attached to this report.

The well is situated on the western side of the village (see plan), and at the time of writing is 288 feet deep. Water is expected to be met with at about 300 feet, which is the depth of the old well, said to have been sunk 14 generations ago, on the eastern side of the village, and about $\frac{1}{2}$ mile distant from the new one.

A glance at the vertical section will show that several of the beds, Nos. IV, V, VII, XII, passed through above the coal contain nummulites, and that a thick band of nummulitic limestone rests immediately upon the coal. Some distance below the latter there is a band of the unctuous clay called 'Multani Mitti' by the natives, which also belongs to the nummulitic series, so that the age of the coal is established as nummulitic or lower eocene. It may be mentioned that the coal of the Salt Range in the Punjab also belongs to this period, and occurs in a similar position beneath a thick band of nummulitic limestone. That the conditions necessary for the formation of coal seams were widely distributed in India at this period is proved by the fact that workable coal of the same age occurs not only in the Punjab, but also in Baluchistan, in Jammu territory, and to the east in Assam and Burma.

The coal as found in the well at Palana has a distinctly woody texture with a dark brown rather than black colour, and does not soil the fingers. In these characters it resembles the cretaceous coal of Assam rather than the nummulitic coals, and it also resembles the former in containing numerous specks and nests of fossil resin.¹ When exposed to the atmosphere it disintegrates rapidly, and becomes very friable, and is thus not well fitted for use in ordinary steam engines, as the small fragments and dust are liable to choke the boiler tubes. This difficulty can however be overcome, I believe, by the use of special methods of stoking. An analysis made in the Geological Survey Laboratory by Mr. Blyth gave the following result :—

Moisture	8.20
Volatile matter	42.72
Fixed carbon	39.28
Ash	9.60
	100.00

Sinters slightly, but does not cake.

Ash, light brown.

Calorific power in heat units (centigrade) 7,293.

Evaporative power, 13.58.

This indicates a fuel that will burn rapidly on account of the large amount of volatile matter, but will be somewhat deficient in heating power, owing to the comparatively small percentage of fixed carbon. The small percentage of ash is of course in its favour. The seam contains strings of iron pyrites but apparently not in large quantity, and the fragments can easily be picked out by hand.

In order to form an opinion as to the area over which the coal is likely to be found, we require to know first, whether the coal as found at Palana is a mere pocket, or whether it extends to any considerable distance from the well, and whether within that area it preserves a workable thickness, and secondly, what is

¹ Medlicott, Rec. G. S. I., Vol. I. p 13. The nummulitic coal of the Salt Range also contains specks of the same substance.

the extent of the formation in which it occurs, in order that we may determine in what direction further search should be made either by boring or well-sinking. With regard to the first point, the evidence afforded by the Palana well is, it must be confessed, somewhat disappointing. The section shows that on one side of the well the thickness of the coal is 8 feet, while on the other at a distance of only 10 feet the thickness is reduced to one half of this. The presence immediately above the coal of a thick band of limestone makes it appear very probable that this irregularity is due to erosion of the coal seam, during the changes of level that must have taken place between the period of growth of the vegetation that formed the coal, and the period of formation of the limestone, a marine deposit. Whether this erosion was merely local or whether it swept away the coal over a large area can only be determined by actual excavation. I had some cuttings made in the mound of sand and debris surrounding the old well at Palana, in the hope of finding whether coal had been passed through when that well was sunk, but with negative results, for though some dark-coloured patches were found, no fragments of coal were discovered. This is not surprising however when we consider that during the lapse of so many hundred years any coal that may have been brought up must have become entirely disintegrated, and would have been carried away long ago by the violent winds so frequent in the desert.

As to the second point, the extent of the formation in which the coal occurs, the information at our disposal is at present very meagre. As mentioned above, no rock is seen at the surface for many miles round Palana. To the west the nearest rock seen is in an elevated ridge, running from near Kolaith, about 20 miles due west of Palana, towards Bikanir. This is mainly composed of sandstones, which are of greater age than the nummulitics, but at the southern end near the village of Mar there are some quarries of the clay known as 'Multani Mitti.' There are several bands of this substance in the Palana well, but those above the coal, Nos. IV and VIII in the section are much inferior in quality to the Mar rock, and the only band to be compared with it is No. XVI which occurs at 66 feet below the coal. Moreover, no limestone or coal is seen below the clays at Mar and it is therefore probable that these are the outcrop of beds below the coal horizon, and that the outcrop of the coal would occur more to the east, in the sandy country between Palana and Kolaith.

To the east and south of Palana again no rock is seen at the surface, but in a well at Surpura, the second station south from Bikanir on the railway, at a depth of 120 feet from the surface, a band of white clay was passed through which closely resembles the band No. III in the Palana well, at 39 feet from the surface. This band in the Surpura well is 50 feet thick, and if these are portions of the same band the coal horizon should occur at a depth of about 330 feet in the Surpura well, of some 40 feet below the depth to which the well has been sunk. A boring carried down from the bottom of the well would soon decide this point, and in case limestone is met with before coal is found, should certainly be carried down to the base of the limestone.

As regards the steps to be taken in order to prove the extent of the seam discovered at Palana, I recommend that headings should be driven from the sides of the well in four directions at right angles to each other through the coal itself. The limestone above the coal should make a fairly sound 'roof' to the workings,

so that it should hardly be necessary to timber them, if they were not wider than 4 feet. The coal extracted, supposing it to be continuous as far as the headings are carried, with an average thickness of 6 feet, would more than pay the cost of driving the headings.¹ Afterwards, supposing that a sufficient amount of coal is proved to make it worth while to start mining on a large scale, the colliery should be laid out and superintended by a properly qualified miner. When the existence or absence of coal has been proved to as great a distance from the well as can be reached by headings, borings might be put down in the surrounding country. But at present, until the conditions under which the coal occurs at Palana have been ascertained, it would hardly be advisable to incur the great expense entailed by borings with so doubtful a prospect of receiving any adequate return for the expenditure.

In conclusion, it may be well to mention that the occurrence of this coal at Palana has no bearing whatever on the question of the existence of the Gondwana coal measures in the desert of Western Rajputana; a question fully discussed by Mr. Oldham in 1886.² The Palana coal belongs to an entirely different and much later period of coal formation, and the existence of the Gondwana coal measures in this region still remains an open question.

*An Account of the Geological specimens collected by the Afghán-Balúch Boundary Commission of 1896. By THOMAS H. HOLLAND, A.R.C.S., F.G.S., Officiating Superintendent, Geological Survey of India (with plate XV.)*³

I.—INTRODUCTION.

The geological specimens collected by Dr. F. P. Maynard and the other members of the Afghán-Balúch Boundary Commission can mostly be matched by the

¹ If the dimensions of the heading are 6 × 4 feet, the yield of coal for every 100 feet driven would be 80 tons. This could be raised and delivered on the railway, about 10 miles distant, for certainly less than ₹10 per ton, and as the present cost of imported coal is ₹30 per ton, the saving on every ton delivered would be very large, even allowing for a considerable difference in heating power.

² Records, XIX. 122.

³ This paper was read before the Asiatic Society of Bengal in December 1896, and is printed here as it is considered more convenient that it should be published in the Records of the Geological Survey than in the Journal of the Asiatic Society. At the time it was written the specimens described were believed to be the only ones brought back from the Boundary Commission, but a paper read by Lieutenant-General C. A. MacMahon to the Geological Society of London on 24th March 1897 shows that this was not the case. Although it would have been more convenient for the whole of the specimens to be described by one individual, the incompleteness necessarily consequent on the absence of the specimens described by Lieutenant-General C. A. MacMahon does not seem sufficient reason for not publishing Mr. Holland's observations on these rocks collected from a region of which so little is known. The description of the physical features of the route is omitted as it will be found in Captain McMahon's contributions to the Geological and Royal Geographical Societies in London during the present year. *Ed.*

rocks obtained by the officers of the Geological Survey of India who have worked over a portion of the country crossed by the Boundary Commission, and on adjoining areas in both Balúchistán and Afghánistán.

Many of the specimens were evidently detached from their original beds and have suffered the usual results of exposure to weather. As it seems likely from the nature of the country that the specimens have not been far removed from their original positions, a brief record of their petrological character will be useful to future travellers who may have opportunities of supplementing the work of the Commission by tracing the rocks to their places *in situ*, and so obtaining the data necessary for an investigation of their geological relations.

II.—PETROLOGICAL CHARACTERS OF THE SPECIMENS.

The rocks collected are principally of igneous origin, the majority being either the direct or the secondary results of volcanic action. Those obtained in the eastern half of the route followed by the Commission are principally acid rocks, granites, eurites and rhyolites; whilst those collected further west—west of Robat I—are mostly diorites and andesites with their corresponding volcanic agglomerates.

A.—PLUTONIC ROCKS.

GRANITITE.—Specimens of granitite obtained from the Khwája Amrán range resemble those previously collected by Mr. C. L. Griesbach and Lala Kishen Singh of the Geological Survey of India. The specimens obtained from a peak near Shili Kach (Lat. $30^{\circ}10'$; Long. $66^{\circ}13'$) were biotite-hornblende granitites. Under the microscope they show signs of crushing, the felspars being frequently broken and the quartzes giving undulose extinctions. Plagioclase is the predominating felspar. Green hornblende and brown biotite are the only ferromagnesian silicates. Sphene occurs in large crystals; small granules of zircon and lumps of magnetite are common. The felspars frequently form micrographic intergrowths with quartz. The rocks show signs of slight decomposition, with kaolinization of the felspars, formation of epidote and loss of pleochroism in the hornblende and biotite.

GRANITITE-EURITE.—On the Koh-malik-do-khand (Lat. $29^{\circ}40'$; Long. $63^{\circ}33'$) rocks occur of the composition of granitites and with the structure of eurites. The specimens collected, however, though containing an abundance of plagioclase felspar, are poor in ferromagnesian silicates. In some specimens porphyritic plagioclase crystals are the most prominent constituents, associated with a pale enstatite, and a few flakes of biotite, granular patches of magnetite are probably the result of fusion of a previous hornblende. Magnetite occurs also in larger lumps. The groundmass shows a fluidal arrangement of the microlites of felspar and probably granules of quartz.

Some of the specimens are encrusted with a white, radiating zeolite which exfoliates before the blowpipe and fuses to a vesicular glass. It has a hardness of 4.5 and a specific gravity of 2.21.

Eurites with much plagioclase felspar occur also on the hills south and west of Barábcháh (Lat. $29^{\circ}25'$; Long. $64^{\circ}5'$).

DIORITE.—*Quartz-diorite.*—Some of the specimens grouped with the diorites

approach the granites in composition, whilst others, in which quartz is wanting, are evidently more basic. An example of a quartz-diorite (quartz-hornblende diorite) was obtained near pillar No. 186 on the Koh-i-malik Siah range, at the western extremity of the line of march (Lat. $29^{\circ}50'$; Long. $60^{\circ}55'$). The rock showed a very distinct flow structure, and, from the description of its mode of occurrence, probably occurred as a dyke.

Mica-augite diorite.—More basic diorites occur associated with the quartz-diorite of the Koh-i-malik Siah range. In one of the specimens biotite, developed ophitically around its associates, stretches across large areas and produced a well marked lustre-mottling in hand specimen. Augite occurs in colourless crystals frequently twinned. These two minerals form a large proportion of the rock. Zoned granules of plagioclase form the matrix of the rock, in which grains of magnetite are plentiful, whilst apatite, sphene and zircon are rare. Calcite occurs as a secondary product of decomposition.

Aphanite?—An altered form of a rock probably related to this group occurs in the Sargu hill, cropping up in the plain west of the Khwája Amrán (Lat. $30^{\circ}23'$; Long. $66^{\circ}12'$). The rock has a fine grained matrix in which there are large quantities of black, opaque granules mixed with numerous crystals of plagioclase approaching oligoclase in composition. The black granules are probably the result of the reheating of the rock by some subsequent intrusion with the usual destruction of hornblende microlites. Amongst the glomero-porphyrific groups occur crystals having the shape and fracture of olivine, but their internal structure has been altered beyond recognition. Basic and ultra-basic igneous rocks have been found by Mr. Griesbach associated with the granites of the Khwája Amrán, and it is likely that the specimens collected by the Boundary Commission are only altered forms of better preserved types in the Survey Collection.

B.—VOLCANIC ROCKS.

RHYOLITE.—The volcanic rocks containing silica as free quartz are apparently the true representatives of the granites of the same area, containing always a marked quantity of plagioclase felspar and having the same ferromagnesian silicate, biotite predominating. Specimens containing good examples of bi-pyramidal quartz crystals corroded by the magma were collected at the crest of the Shibian pass (4,000 feet), in the hills north of Chageh (Lat. $29^{\circ}17'$; Long. $64^{\circ}45'$).

ANDESITE.—Andesites are by far the most numerous amongst the specimens of volcanic rocks collected by the Boundary Commission. They usually contain hornblende in some form as the ferro-magnesian silicate, and generally resemble the andesites in the Survey collection obtained by Surgeon-Major Brazier-Creagh, from South-East Persia.¹ The characters of the rocks collected over the western part of the route followed by the Commission are so strikingly like those of South-east Persia that there seems little doubt about their being part of the result of the same geological disturbance, of which the hot sulphur springs still left represent the final stages of a dying volcanic outburst.

The most interesting example of this group contains the comparatively rare soda amphibole, arfvedsonite, as its only ferromagnesian silicate. The rock has a rusted vesicular groundmass, with the cavities partially filled in with chalcedony.

¹ See pt. IV of this volume.

The large phenocrysts of plagioclase are strikingly zoned by inclusions of the glassy matrix. The crystals of arfvedsonite show the usual outlines and cleavage of amphibole, with a well marked pleochroism of—

a = light greenish yellow.

b = yellow.

c = deep sherry red.

Extinction angle 5° , $c \wedge c$. The crystals are easily fused before the blowpipe. Specimens of this rock were collected near the Koh-malik-do-khand (Lat. $29^\circ 40'$; Long. $63^\circ 30'$).

Hornblende-andesites were also obtained in the same area on the hills south of Robat I, and, like nearly all the andesites, show the opaque granular resorption borders so frequently displayed by the hornblendes in rocks of this class.

Andesites were also obtained near Kani (Lat. $29^\circ 35'$; Long. $65^\circ 5'$); Gharibo hill, north of Dárband (Lat. $29^\circ 17'$; Long. 63°); Amír-cháh (Lat. $29^\circ 16'$; Long. $62^\circ 32'$) and at Saindak (Lat. $29^\circ 20'$; Long. $61^\circ 40'$).

Nearly all the andesites show signs of decomposition and are impregnated with carbonate of lime.

BASALT.—Porphyritic, amygdaloidal, basic rocks occur near boundary pillar No. 165, west of Samuli (Lat. $29^\circ 27'$; Long. $63^\circ 56'$) the rocks are highly decomposed, and, besides relics of plagioclase phenocrysts, contain remains of what were probably olivine crystals, now completely devoid of original material.

A basalt dyke four feet wide was observed in the granite crossing the boundary into the Afghán territory near Barabchah (Lat. $29^\circ 26'$; Long. $64^\circ 5'$).

VARIOUS VOLCANIC PRODUCTS.—*Pumice* was picked up in a river bed, 6 miles east by north of Amír Cháh (Lat. $29^\circ 17'$; Long. $62^\circ 34'$) and was probably derived from an extinct volcano south by east of the place. The specimens contain occasional fragments of felspar crystals; the vesicles are drawn out into bands and are thoroughly impregnated with carbonate of lime.

Volcanic agglomerates, composed generally of rocks related to the andesites and basalts, were found at various places; for example, at Kambar Koh, a hill west of the Sarlat range; at Gazechah (lat. $29^\circ 32'$; long. $64^\circ 50'$); on the Koh-malik-do-khand, containing fragments of augite andesite with a ferruginous cement, and, like all the other volcanic agglomerates, considerably decomposed.

Highly baked volcanic ashes were obtained in the Gharibo hill near Dárband.

Amongst the volcanic products also should be mentioned the *sulphur*, *selenite* and *galena* which occur near Saindak, which has already been referred to as the locality from which specimens of andesite were obtained. A peculiar soft ferruginous lithomarge, known as *mak* or *giri*, is obtained from the same place, and is collected and carried to Kandahar for dyeing purposes by *kakars* and *babars*. *Sulphur* and *alunogen* were also obtained in the Koh-i-Sultan.

The most interesting amongst the materials indirectly connected with volcanic action are the *travertines* of the Koh-malik-do-khand, from which various andesites were obtained. The travertine forms horizontal strata three or four feet thick, resting on gravel and consisting partly of white, columnar aragonite and partly of a yellowish translucent calcite in alternating layers. The aragonite has a specific gravity of 2.92 and the calcite, 2.72. Such alternate layers of the dimorphous carbonate of lime were probably the result of formation from water at different

temperatures. This is the substance evidently referred to by Dr. J. E. T. Aitchison in his "Notes on the Products of West Afghanistan and of North-East Persia" (*Trans. Ed. Bot. Soc.*, XVIII, reprint, p. 7), as limestone composed of layers of different colours together with alabaster and "chrysolite." In a note at the end of his paper Dr. Aitchison says the so-called "chrysolite" specimens were identified in Edinburgh as aragonite containing traces of strontia. I am indebted to Dr. Maynard for calling my attention to this note.

C.—SEDIMENTARY ROCKS.

The few specimens of sedimentary rocks collected by the Boundary Commission being without notes as to their stratigraphical relations deserve only a brief record of their characters. Shales, limestones, quartzites and conglomerates were brought from the neighbourhood of the Khwája Amrán. In the conglomerate the pebbles were slightly rounded and composed of quartz, quartzites and granitic rocks, the last sometimes showing most perfect micrographic structures. The quartzites and conglomerates are impregnated with infiltrated carbonate of lime. Coral limestones in rolled fragments were found at the foot of the Sarlat range, and on the east side of the gorge at Amír Cháh.

D.—ECONOMIC MINERALS.

Near Kartárkar, Kacha Koh, and Saindak which are evidently close to the site of a dying volcanic centre, specimens of excellent transparent selenite, native sulphur and galena were obtained. Sulphur and alumstone were also obtained in the Koh-i-Sultan near the site of an extinct or dying volcano. The soft ferruginous lithomarge, known as *mak* or *giri* and used for dyeing, occurs in the hills south of Saindak and in the Koh-i-Sultan.

The remains of extensive copper smelting works were discovered near Robat II (Lat. $29^{\circ}49'$; Long. $61^{\circ}6'$).

A large dried up salt marsh occurs near the northern end of Lora Hamun (Lat. $29^{\circ}27'$; Long. $64^{\circ}52'$). The salt being in the vicinity of recently extinct volcanoes is probably of volcanic origin.

Limestone occurs at various places, and a yellow translucent calcite was found in the neighbourhood of the Koh-malik-do-khand.

Notes from the Geological Survey of India.

Dysluite from Madras.—A new mineral and a new locality for a rare mineral may be recorded. Dysluite, the zinc-iron-manganese variety of gahnite has been found in the corundum-bearing granite of Padiyur in Coimbatore, in veins with felspar, quartz and zircon.

Columbite from Hazaribagh.—A new locality for this mineral may be recorded, specimens from the Government forest of Koderma in Hazaribagh having been presented to the Museum by Mr. Gow Smith. The present specimens differ from those previously recorded from Nawadih (Rec. xxvii, p. 8) in having a considerably higher specific gravity, *viz.*, 6.19 as against 5.54.

EARTHQUAKE OF 12TH JUNE.

On the afternoon of the 12th June, at five o'clock in the afternoon, Calcutta was startled by a shock of earthquake such as it had never felt before; many houses were more or less injured, the steeples of two churches broken off, and hundreds of people rendered homeless. Soon, however, it became evident that other places had suffered far more severely than Calcutta. Railway and telegraphic communication was cut off and it was only as the days wore on and news tardily arrived from the north and from the east that we found ourselves faced with a cataclysm which rivaled the classic earthquake of Lisbon in violence and extent.

No sooner were we aware of the scale of the event we had to deal with than preparations were made for its thorough investigation. The immediate succession of the rainy season on the earthquake rendered it imperative that observation of its effects should be made with all possible promptitude, and every officer of the Geological Survey then in Calcutta was despatched to observe and investigate. At the same time orders had been issued by Government to the local authorities to report fully on the effects of the earthquake. All the telegraph offices throughout India were instructed to report the time at which it was felt, and similar information was called for from all the station masters on the lines of Railway within the area likely to be affected. Circulars have also been widely distributed and communicated to the press, which has readily assisted in the endeavour to collect information.

The replies to these circulars and the reports called for from Government officials are now pouring in at a rate which defies satisfactory analysis, but some of the main facts about the earthquake, which have been already established, may be noticed here.

The area over which the earthquake was felt is enormous. On the east it has been reported as felt from the furthest extreme of Assam, at Mogok, Magwe, and Akyab in Burma; on the south, at Masulipatam in Madras, and Ellichpur in Berar; from Surat, Ahmedabad, Mount Abu, Ajmere, Panipat and Simla on the west. On the north it was felt at Katmandu; at Gnatong on the frontier of Sikkim and Thibet, it was severe enough to overthrow some of the barrack chimneys, and it is reported to have been felt at Lhassa. Besides these observations which are free from doubt, the shock appears to have been just perceptible to a few people, particularly sensitive or specially favourably situated in Dharmasala, Madras and Pegu. Omitting these last, there remains the fact that the range of the shock was over 24 degrees of longitude and 16 degrees of latitude or an area of over 1,500 miles in length and 1,000 in width, or, say, 1,275,000 square miles in all.

The area over which the shock was destructive is also great; from Darjiling, Monghyr and Calcutta on the west, to Jorhat on the east, damage and occasional destruction was caused to buildings, but this destructive force reached its maximum in Shillong, Cherrapunji and Tura. In Shillong, it may be said almost without exaggeration, that not one stone has been left standing on another. All masonry buildings have been levelled to the ground, and this, not by overthrow, but by a shattering of the walls into fragments, on the top of which the roof subsided. The nature of the destruction will be best understood by a reference to Plate XVI, which gives a view of Government house after the earthquake, drawn from a

photograph taken by Mr. F. H. Smith, of the Geological Survey. The other drawing on the same plate shows the influence of construction; the central portion of the hotel was built of stone and has been shaken to the ground. The two ends, however, which were additions to the original building and built of a wooden framework filled with reeds plastered with mud, have stood though severely shaken.

At Shillong it is possible to form some idea of the violence of the shock. In 1882 a seismometer composed of a series of cylinders of various diameters was set up. The largest of these is 12" by 9" diameter, and the whole series was overthrown to the north-eastwards. According to Omori's formula a cylinder of these dimensions would be overthrown in a direction away from the origin of the shock, as these were, by a velocity of wave particle of 2 feet per second and if we take the period of vibration as 1 second which is about that of the more severe shocks in Japan, this would imply a range of motion of 7.4 inches. In other words, the violence of the shock at Shillong, while it lasted, was at least equal to a backward and forward shake of 7 inches repeated 60 times a minute. If the range of movement was less, the rate of shaking must have been greater; if the movement was slower, the range of motion must have been greater in the same proportion.

That few structures, except those most strongly braced together or possessed of a very great flexibility, could stand this is not difficult to understand, and the violence of the to and fro movement will perhaps be best appreciated from the fact that the very boundary pillars have been shaken to pieces and heaps of broken road metal by the roadside were scattered out in layers of a few inches deep.

Earth-fissures and sand-craters are reported throughout the alluvial plains from Purneah on the west, to Jorhat on the east. They are, as is well known, only superficial and secondary results of the earthquake wave, but afford, among other information, instances of the extraordinary manner in which observation may be influenced by imagination. Numerous accounts speak of a strong sulphurous smell of smoke issuing from the vents and of hot, even boiling hot, water being poured forth. More temperate accounts show that the sulphurous smell was that of decaying vegetable matter, that the smoke was dust, and that the heat of the water was no greater than was to be expected in the middle of June. Closely allied in origin to the sand vents was the filling up of all the drainage channels, tanks and wells over large areas. That this was not due merely to an outpouring of sand, but to an actual forcing up of the bottoms of the hollows is shown by the effect on bridges, whose piers have been forced bodily upwards, as is shown in Plate XVII, reproduced from one of the admirable series of photographs taken by Messrs. Kapp & Co. of Calcutta. The other figure on the same plate, reproduced from one of the same series of photographs, shows how the rails have been affected by the movement of the surface alluvium consequent on the shock.

The rate of transmission of the wave was very high, in fact it has been stated in newspapers, and frequently spoken of, as having been felt simultaneously throughout Northern and Eastern India. Such was not the case, however, though the time the wave took to travel from its origin to the furthest point at which it was sensible to unaided observation does not appear to have been more than 8 minutes. The very large number of time observations, of every degree of accuracy, which have been communicated, have not yet been discussed, and no definite statement can be made, but a few selected at random as apparently good give an average rate of

transmission of about 10,000 feet per second or over 112 miles per minute. This result indicates the order of magnitude of the figures we have to deal with, though it cannot be accepted as final, or more than very approximate. The prevalent idea of the simultaneousness of the shock is disproved by a quaint report by the telegraph master of Chupra, who relates that he was working Durbhunga when there was suddenly a stoppage due to the earthquake at Durbhunga, and the signaller leaving the instrument there, and immediately afterwards the earthquake was felt by him. According to the daily papers a similar incident took place at Dhubri, which was at the time in communication with Goalpara.

Beyond the area over which the earthquake was felt its effects were traced instrumentally at Bombay, where the instruments in the magnetic observatory were affected by a disturbance commencing between four and five minutes past four, local time, or 16 h. 34 m. Madras time, that is, 6 minutes later than the shock was felt at Calcutta, and about 9 minutes after the probable time at which the shock started on its way from the place of origin, somewhere below the Garo or Khasia hills.

The effects of the shock are said to have been traced at Grenoble; and at Edinburgh a letter from Mr. Heath, Assistant Astronomer, to *Nature*, gives the time at which the tremors were first felt as June 11th, 23 h. 18 m. G. M. T.; they lasted about 10 minutes and then ceased, and violent oscillation again set in at 0 h. 32 m. G. M. T. of 13th June and continued up to 1 h. 12 m. They were equivalent to a tilting of the ground through 20 seconds of arc. Greenwich mean time June 11th, 23 h. 18 m. (astronomical) corresponds to Madras time 16 h. 39 m. of 12th June, (civil); 0 h. 32 m. G. M. T. of 13th June corresponds to Madras time 17 h. 53 m. of 12th June. If both these sets of tremors were due to the same earthquake the first must have travelled the distance from the origin to Edinburgh, starting at about 16 h. 25 m. Madras time, in 14 minutes, the other in 1 h. 28 m.

These few notes form no adequate account of the earthquake; this is in preparation, but the collection and discussion of the information will take some time. Meanwhile what has been written will serve to show the order of magnitude of the cataclysm of 12th June 1897, an earthquake unsurpassed by any since the great Lisbon earthquake of 1st November 1755, and rivalling this in magnitude of the area over which it was felt, surpassing it indeed if we exclude the doubtful records of the earlier shock.

31st July 1897.

R. D. OLDHAM.

GEOLOGICAL SURVEY OF INDIA.

Shillong, 20th Jan 1921

Records No. 1 X Pl. 11



GOVERNMENT HOUSE SHILLONG



FERNDALE HOTEL SHILLONG

GEOLOGICAL SURVEY OF INDIA.

Earthquake of 12th June 1897

Records, Vol XXX II XVII



BRIDGE ACROSS NALLAH AT HALDIBARI.



photos. by Messrs F Kapp & Co

LINE BETWEEN HALDIBARI AND MOGHAI HAT.

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1897.

Specimens of Muscovite; Muscovite with Garnet and Tourmaline; thin Quartz plates from Muscovite; a large crystal of Garnet; and 3 specimens of Columbite, from the Koderma Government Forest, Hazaribagh district.

PRESENTED BY A. GOW-SMITH,

KODERMA, HAZARIBAGH DISTRICT.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.

1897.

November.

On Nematite from Afghánistán: by F. R. MALLETT, late Superintendent, Geological Survey of India¹.

In 1887, when I was in charge of the Geological Survey laboratory, a specimen of a mineral recently discovered in Afghánistán, was sent by the British Agent at Kábul, with a request for information as to its nature and value. A few qualitative tests sufficed to show that it was nematite. A quantitative analysis was subsequently made by Mr. T. Blyth, which is published in the fourth part of the Manual of the Geology of India, page 161. As it seemed possible that the mineral might be capable of some useful application if plentiful, and it was, in any case, of mineralogical interest, a request was made to the Agent for further information about it, including locality where it was found; and for additional specimens. The information asked for did not appear to be procurable, but a box full of the mineral, containing, as far as I remember, about 100 lbs. of the substance, was sent to the Geological Museum. When retiring from India in 1889, amongst a few specimens of Indian minerals which, with the permission of the then Director of the Survey, Dr. King, I brought to England in the hope of being able to examine them at some future time, was a picked sample of the nematite in question. It is however, only recently that circumstances have allowed my making a commencement of such work, by an examination of the mineral I have alluded to.

The specimens sent were all very similar to each other in outward appearance, but differed more or less in the amount of alteration they had undergone, which could be roughly judged by eye through variations in colour and translucency. The sample, I selected, was one of those which appeared to have undergone the least change.

It consists of a mass of straight, very fine, highly flexible and elastic, easily separable fibres eight inches long, which seem clearly to have formed part of a vein. Some particles of serpentine, adherent to one end of the specimen, indicate that the rock in which brucite has generally been found elsewhere is the probable matrix in Afghánistán also. The ends of the specimen show that the fibres were not perpendicular to the walls of the vein, as is more usually the case with fibrous minerals, but made an angle with the walls of about 20° (or 160°). Whether this was due to a local twist in the direction of the walls at the spot from

¹ Reprinted from the Mineralogical Magazine, Vol. X, No. 52, pp. 211—214.

which the specimen was taken, or is common to the whole vein, I do not know¹. Both ends of the specimen show very obvious signs of chemical alteration, but the central part, for about five inches, is, to all outward appearance, both to the naked eye and under the microscope, perfectly fresh; and that it has not undergone any considerable change is shown by the absence of both carbonic acid and ferric oxide. The sample used for examination was of course taken from this central portion.

Transverse to the direction of the fibres the colour by reflected light is sea-green with a silky lustre: by transmitted light pale to dark sea-green according to the thickness of the specimen; the extreme red and the violet being the rays most strongly absorbed, together with the blue if the thickness be sufficiently great. Looked at by transmitted light parallel to the direction of the fibres, the colour is very similar. In a specimen an inch long the colour is sufficiently intensified to approach a pale emerald green. The colour of the mineral is doubtless due, mainly at least, to the unusually large amount of ferrous oxide it contains. Neither transverse nor parallel to the direction of the fibres is there any perceptible dichroism.

A section perpendicular to the direction of the fibres² shows no dark cross or rings in convergent polarised light; in parallel light with crossed nicols the field is rather brightly illuminated, and revolution of the nicols together does not alter the illumination. A cylinder of the fibres, again, lying parallel to the stage of the microscope, exhibits double refraction, and no alteration in the phenomenon is observable during a revolution of the cylinder on its own axis. The axis of greater optical elasticity is in the direction of the fibres. The above observations are in consonance with the statement of Lévy and Lacroix that in nemalite "*les fibres sont allongées suivant un des côtés de l'hexagone et négatives*,"³ and with the optically positive character of brucite, nemalite included. But they apparently indicate that the vertical crystallographic axes, *c*, in the different fibres (which are so minute that in a cross section they are individually quite invisible under the microscope⁴), lie, not in parallelism with each other, but in varying directions in the plane perpendicular to the cross section of the fibres.

The value obtained for the specific gravity, at 60° F. is 2.454; a high result which must be ascribed to the large amount of iron present.

The mineral gave on analysis (free from hygroscopic moisture):—

		Oxygen ratio. ⁵
Magnesia	62.00	24.58
Ferrous oxide . . .	7.87	1.75
Manganous oxide . .	tr.	
Water	29.55	
Silica	.38	
	99.80	
		26.33 = 1.003
		26.24 = 1

A faint trace of lime was detected spectroscopically.

¹ Prof. Hidden, who was present when this paper was read, remarked that in the nemalite of Hoboken, New Jersey, there is a similar obliquity between the direction of the fibres and that of the walls of the vein.

² I am indebted to Professor J. W. Judd, C.B., for kindly having the section cut for me, and also for several references bearing on the subject of brucite.

³ *Les Minéraux des Roches*, 1888, p. 612.

⁴ With linear magnification of 180.

⁵ Mg = 24.36, Fe = 56.0, H = 1.0076.

The only point in which the above figures differ noticeably from Mr. Blyth's is in the smaller amount of iron. But the portion used in his analysis was from a different specimen, obtained at a different time, and possibly from a different part of the vein; and more or less variance in the relative proportions of the isomorphous oxides is what might be expected.

The silica is left undissolved by hydrochloric acid in the form of translucent tangled fibres, which dissolve in a hot solution of sodium carbonate. They are indistinguishable in appearance from the silicious fibres which remain when chrysotile is decomposed by the same reagent. As nemalite and chrysotile are both usually found under similar conditions—in the form of veins traversing serpentine—it seems not unnatural that the two allied magnesian fibrous minerals should coexist, intimately mixed, in the same vein, and it appears not improbable that such is the case in the substance under discussion.

If, then, the silica be regarded as a constituent of chrysotile, and to the latter be assigned the theoretical composition of the mineral, with the magnesia and iron in the same proportions, relatively to each other, as in the nemalite, the above analysis will stand as follows:—

	Chrysotile.	Nemalite.	Calculated to 100.	Oxygen ratio.
Magnesia . . .	35	61.65	62.32	$\left. \begin{array}{l} 24.71 \\ 1.76 \end{array} \right\} 26.47 = 1.001$
Ferrous oxide . .	04	7.83	7.92	
Manganous oxide . . .	...	tr.	tr.	
Water . . .	11	29.44	29.76	26.43 = 1
Silica . . .	38			
	88	98.92	100.00	
	99.80			

Granting the existence of the chrysotile, whether it should be regarded as formed synchronously with the nemalite, or as present owing to one mineral having been altered into the other, I do not know. As previously remarked, the substance analysed showed no indication of change, unless the presence of silica be regarded as such. On the other hand, a portion of the substance near the end of the specimen, where it was obviously changed, contained 2.26 per cent. of silica fibres = 5.28 per cent. of chrysotile, or six times as much as the portion analysed. But this excess of silica was accompanied by the presence of carbonic acid and ferric oxide, which might therefore perhaps be expected to accompany the smaller amount of silica (.38 per cent.) also, if the latter were due to alteration of the nemalite; and the large percentage of silica may be caused merely by original unequal distribution of chrysotile through the specimen.

Near the ends of the specimen the original green colour is changed to a light hair-brown, the mineral still retaining its translucency, the alteration being due to a very partial peroxidation of the iron. Beyond that again the fibres are white, with a pale reddish tinge, and comparatively opaque. These (besides the silica mentioned above) contain a considerable quantity of carbonic acid, owing to the nemalite having been more or less fully converted into hydromagnesite; and the ferrous is largely, or entirely, changed to ferric oxide. There is also a certain amount of non-fibrous, and scaly, or in part stellate-lamellar hydromagnesite on the ends of the specimen, formed, apparently, by deposition on the nemalite, not

by alteration *in situ*. This hydromagnesite encloses some magnetite, which may perhaps be taken as representing part of the ferrous oxide of the nemalite (from some other portion of the vein), from which the deposited hydromagnesite was probably formed.

Fibres of the nemalite held in the zone of fusion of a Bunsen burner, shine with the rather high luminescence of ignited magnesia. As they possess considerable tenacity, as well as much flexibility, there is little doubt that it would be possible to weave some kind of fabric from them, which might be used for incandescent mantles. But in face of the superior luminosity of the materials already employed, and the easier process of manufacture, there is little reason to anticipate that such an application of the nemalite would be commercially profitable. And, further, even were the use alluded to more promising, nothing is known at present as to the quantity in which the mineral could be obtained.

On a Quartz-barytes rock occurring in the Salem district, Madras Presidency. By T. H. HOLLAND, A.R.C.S., F.G.S., Officiating Superintendent, Geological Survey of India (with Plate XVIII).

When barytes occurs as one of the "spars" of compound mineral lodes, such, for instance, as its common occurrence in galena lodes, the constituent minerals generally present the "banded" and "comby" structure which is supposed to be the result of successive deposition of minerals in a gradually widening fissure. The same mineral also occurs infilling cavities in amygdaloidal traps, cavities in fossils, fissures in limestones or sandstones, and often also as a cement binding together the sand-grains in the latter rock—occurrences which suggest a secondary origin for the mineral, and also point to its deposition by precipitation from aqueous solutions. The concretionary nodules found in some clays, and amongst the deep-sea deposits, are also formed by the chemical precipitation of barium sulphate from solution in water.

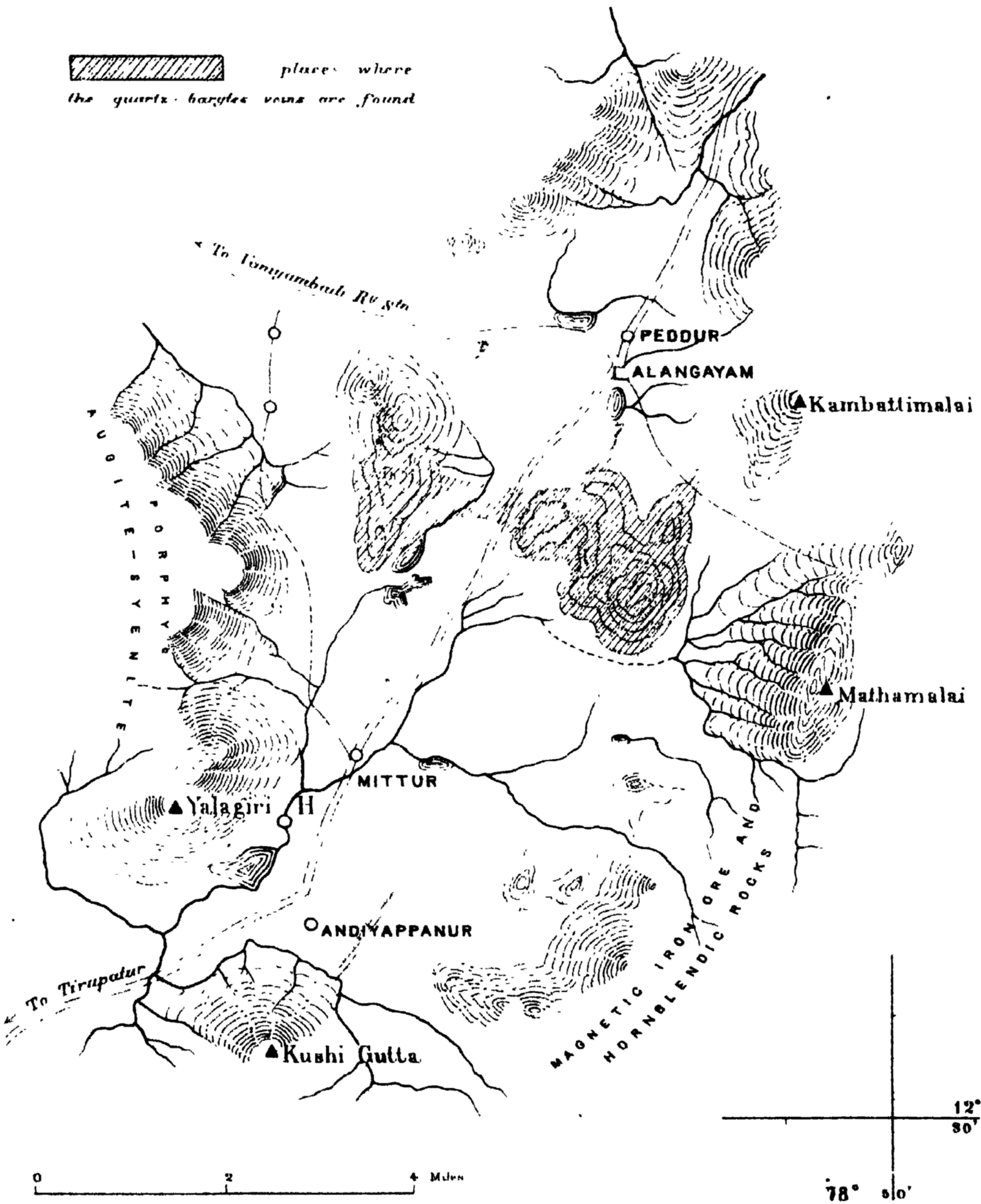
2. But the occurrence of this mineral with quartz, forming a network of veins, such as have recently been discovered in the Salem district, appears to be unique in character, and can hardly be explained by the theory applied to the commoner occurrence of barytes in mineral lodes. About midway between Mittur and Alangayam (lat. $12^{\circ}38'$; long. $78^{\circ}47'$) in the Tirupatur taluk, Salem district, two low hills are found to be formed largely, and as far as could be seen in the southern part of the western hill entirely, of a rock composed of quartz and barytes, whilst numerous veins of the same material are found penetrating the crystalline rocks in the neighbourhood.¹ These veins are found stretching as far

¹ The valley in which the town of Alangayam lies separates the Velagiri Hills, composed principally of a porphyritic augite syenite, from the Javadi Hills, composed of gneissose rocks with which beds of magnetic iron ore are found associated.

GEOLOGICAL SURVEY OF INDIA.

Holland

Records, Vol XXX Pl XVIII



DISTRIBUTION OF THE QUARTZ-BARYTES ROCK NEAR ALANGAYAM.

as Alangayam, a distance of two miles north of the main plexus, and as far as Andiyappanur, a distance of five miles southwards; but in the latter instance the outcrop is only traceable for a distance of half-a-mile in a N.E.—S.W. direction on the south-eastern side of the village of Andiyappanur; but as the main mass of the rock lies to the north-east of Andiyappanur, that is, the direction of the outcrop of the vein, it is more than probable that this vein is merely an offshoot from the main mass south-west of Alangayam. its outcrop being covered by the cultivated alluvium which extends over the intermediate area.

3. The prevailing rock of the area, through which the quartz-barytes rock is injected as veins, is a pyroxenic gneiss, presenting a mottled appearance in hand-specimens, and showing under the microscope a considerable advance towards the change of the pyroxene into amphibole. But in addition to the gneiss, veins of the quartz-barytes rock are found crossing dykes of microgranitic rocks, which, though intruded before the injection of the quartz barytes rock, must have been erupted subsequently to the foliation of the gneiss. Although the actual contact has not been observed, the quartz-barytes vein near Andiyappanur shows a continuous outcrop across, and at right angles to, a very thick dyke of augite-diorite, similar to the common trap-dykes which in South India are generally regarded as the representatives of the Cuddapah lava-flows (*Rec. G. S. I.*, Vol. XXX, p. 16). It is probable, therefore, that the quartz-barytes rock is younger than this trap.

4 The veins of quartz-barytes rock vary in thickness from mere strings to dyke-like masses several feet across, and the fissures which they occupy instead of lying within a few degrees of the vertical, as is commonly the case with undisturbed trap-dykes, are found with their flat surfaces lying at all angles to the horizon.

5. But the size of the veins seems to have no recognisable connection with the sizes of the crystals composing them, even in the thin strings the barytes forms large crystals, and on this account, as much as on account of the colour of the minerals, the rock presents a most remarkable resemblance to an acid pegmatite when first seen in the field. The barytes crystals are scattered through the quartz in a most irregular manner; there is no parallel disposition with regard to the sides of the vein, and no trace of the "comby" structure which so often characterizes mineral lodes. There is, in fact, no reason for supposing that the conditions under which this material was injected into the veins, were essentially different to those under which the material, when of a different chemical composition, crystallizes as a pegmatite. The distances to which some of the veins are found to extend, and their uniformity of composition throughout, show that the substance originally injected must have been in a fluid state. The idiomorphic outlines presented by the barytes, and the complete absence of any other mineral after which it might possibly be pseudomorphous, point to its occurrence as a primary constituent. We conclude, therefore, that, whatever may have been the conditions of temperature under which it was injected, this peculiar rock has been formed by the consolidation of a mobile magma from which quartz and barytes separated as the principal results of its primary crystallization.

6. The veins of this rock are made up principally of quartz and barytes, with which there occur very much smaller quantities of galena, pyrite, ilmenite

hematite and limonite, the last-named two minerals occurring with a dirty clay in the decomposed specimens.

To form an estimate of the relative proportions of quartz and barytes, the two main constituents, 60 specimens were determined by Mohr's specific gravity method by Mr. T. R. Blyth, under Mr. H. H. Hayden's superintendence. The results were as follows:—

	Number of pieces used.	Weight in grammes.	Water displaced in cubic centimetres.
A	1	2799.05	986.30
B	1	1851.10	446.15
C	1	1606.45	555.90
D	1	1650.59	515.54
E	1	1392.95	465.15
F	1	1156.45	341.30
G	25	884.01	261.00
H	6	605.79	227.00
I	4	815.05	299.00
J	3	964.99	317.00
K	2	529.09	189.00
L	2	633.28	235.00
M	2	733.21	234.00
N	2	581.31	202.00
O	1	475.18	180.00
P	1	671.85	245.00
Q	1	826.73	287.00
R	1	721.55	271.00
S	1	739.80	267.00
T	1	589.82	208.00
U	1	475.58	164.00
V	1	564.36	182.00
TOTAL		21268.29	7078.34

The average specific gravity of the rock is thus —

$$\frac{21268.29}{7078.34} = 3.005$$

Knowing then the specific gravity of the rock to be 3.005, and that of its two

principal constituents to be 2.65 and 4.30 respectively, the percentage composition of the rock can be determined as follows :—

Taking x to be the percentage proportion of quartz, $(100-x)$ must be that of barytes, then—

$$3.005 = \frac{100}{x + 2.65 + (100-x) \div 4.3}$$

from which x is found to be 69.2. The percentage composition of the rock is thus—

Quartz	.	.	.	.	.	69.2
Barytes	.	.	.	.	.	30.8
						100.0

This result confirms our decision in rejecting the theory of pseudomorphism after felspar which was considered in paragraph 5; for the proportion of quartz to felspar in pegmatite, at least in the graphic varieties, is quite different (cf. Teall, *British Petrography*, p. 402).

In view of the presence of the accessory minerals mentioned in paragraph 16, a special test for gold was made by Mr. Blyth, with the result that 19 lbs. of the rock yielded gold in the proportion of 13 grains to the ton. Although this is of course well below a profitable minimum, the area seems quite worth further testing on a larger scale.

QUARTZ.

7. The natural colour of the quartz varies from white to grey—the colours of the common vein quartz frequently found in the neighbourhood of intrusive rocks. The true colour of the quartz is, however, generally masked by ferruginous stains produced by rusty infiltrations along the cracks, which are sufficiently numerous to render all specimens of the rock easily friable.

8. Microscopic sections show the quartz to be composed of an aggregate of irregularly interlocking crystals, which are very variable in size, sometimes an inch or two across, and at other times quite microscopic. The white and grey colours, as well as the imperfect transparency of the quartz, are evidently due to the innumerable microscopic cavities seen in section. These cavities are often arranged in bands, and are sometimes filled with liquids containing bubbles. In one specimen of quartz, which was distinctly blue in colour, small zircons and long, hair-like inclusions were abundant. The resemblance of this quartz to that which is found so abundantly in the charnockite series of the same district, suggests the foreign origin of this particular piece, although no further instances of included older rocks have been found.

BARYTES.

9. The barytes occurs as crystals often measuring 2 or 3 inches across, which generally form groups of several individuals. The junction surfaces between the barytes and the quartz often agree with crystal faces of the former mineral. Thus indicating that the period of crystallization of the barytes was on an average in advance of that of the quartz.

10. When transparent the colour of the crystals varies from grey to pink, and

in thin cleavage plates they are colourless; but most of the crystals are disfigured by irregular, cream-coloured patches which are nearly opaque. These patches give the crystals a remarkable resemblance to kaolinized orthoclase when first seen in the field. One specimen showed a zonal disposition of black inclusions.

11. The basal and the prismatic cleavages are perfectly displayed in every piece, whilst thin sections cut parallel to the basal plane show an additional, but noticeably less perfect, cleavage parallel to the brachypinacoid (010). Several determinations made on a basal section gave an average of $78^{\circ} 30'$ and $101^{\circ} 30'$ as the angles between the prismatic cleavage cracks.

12. The perfect display of cleavage cracks facilitates the preparation of sections parallel to the pinacoidal faces for the purpose of examining the optical characters. Sections cut parallel to the macropinacoid (100), that is, at right angles to the basal plane and bisecting the acute angles of the prismatic cleavage cracks, show the biaxial figure in convergent polarised light, from which the positive character of the double refraction is easily proved, whilst the optic axial angle is seen to be small. The line joining the optic axes in these sections lies at right angles to the basal cleavage cracks, consequently the optic axial plane must be parallel to the brachypinacoid (010). The optical scheme is thus—

$$c \quad = \quad \infty$$

which is confirmed by using the quartz wedge on the basal and brachypinacoidal sections.

One of the most interesting features in connection with these sections is the remarkable difference between the colours displayed by the macropinacoidal and those shown by the other pinacoidal sections between crossed nicols. Thin sections cut parallel to the macropinacoid show extremely low colours, as low in fact as the grey, whilst sections of the same thickness cut parallel to the other pinacoids polarise with reds and blues of the first order. This interesting phenomenon is evidently due to the fact that there is a much smaller difference between the maximum and the mean than between the mean and the minimum coefficients of elasticity, or, which is the same thing, the refractive indices α and β approach one another very closely—a fact which finds expression in the narrowness of the optic axial angle. The values of the refractive indices for the D line given by Dana¹ after Arzruni are:—

$$\begin{aligned} \alpha &= 1.63609 \\ \beta &= 1.63712 \\ \gamma &= 1.64795 \end{aligned}$$

We have therefore—

$$\beta - \alpha = .00103; \quad \gamma - \beta = .01083, \text{ and } \gamma - \alpha = .01186$$

Whilst, therefore, the basal sections, containing γ and β , and the brachypinacoidal sections, containing γ and α , show comparatively high double refraction, higher indeed than that of quartz, the macropinacoidal sections, containing β and α , show a very low double refraction, lower even than that of apatite. As one result of this interesting circumstance the small granular crystals of barytes, frequently found filling in cleavage rifts in the larger individuals appear as a brightly polar-

¹ System of Mineralogy, 6th Ed., page 902.

ising mosaic, whilst the macropinacoidal section, forming the principal part of the field, exhibits low grey colours. Owing to the strain phenomena the character of the dispersion could not be made out with certainty; in fact, as a result of this strain the colour dispersion appears to be as often "crossed" as of the rhombic type.

13. The macropinacoidal sections often show a very imperfect lamellar twinning parallel to the brachydome (011). The traces of these twin-planes appear on the basal surfaces as very fine lines bisecting the obtuse angles of the rhombic cleavage cracks. As many of the crystals are noticeably bent, the twinning is probably secondary and due to pressure, as was shown by E. S. Dana¹ to be the case with the so-called michel-lévyte described by Lacroix, and in other instances by Max Bauer.

14. The cream-coloured patches already alluded to are less transparent under the microscope. Apparently the barytes has been altered along these areas and irregular cavities have been produced by removal of the material in solution. In the clear and unaltered parts of the crystals also there are bands of cavities with liquids containing bubbles; but these have a different origin.

15. The average specific gravity of the crystals is 4.30. Examination before the blowpipe gave the usual reactions for barytes, indicating the presence of barium by the apple-green flame and of sulphur by the sulphide stain on silver. Many of the specimens are distinctly fetid when rubbed. A chemical analysis, made by Mr. T. R. Blyth under the superintendence of Mr. H. H. Hayden, in the Geological Survey Laboratory, gave the following results:—

Moisture	0.04
Loss on ignition	0.26
Silica	0.63
Ferric oxide and alumina	0.93
Barium sulphate (Ba SO ₄)	94.15
Calcium sulphate (Ca SO ₄)	4.01
	100.02

The chemical analysis thus confirms the physical evidence as to the great preponderance of barium sulphate in these crystals, and the replacement of a small proportion of the barium sulphate by the isomorphous sulphate of lime accounts for the slightly low value of the determined specific gravity (4.30). Taking the specific gravity of pure barium sulphate (barytes) to be 4.40, and of pure sulphate of lime (anhydrite) to be 2.95, a mixture of the two compounds in the above proportions would have a specific gravity of—

$$\frac{26.16}{94.15 + 4.4 + 4.01 + 2.95} = 4.31$$

which closely agrees with the observed specific gravity of the crystals.

ACCESSORY MINERALS.

16. Compared with the quartz and barytes, the minerals galena, pyrite, ilmenite, hematite and limonite occur in extremely small quantities, and show a tendency to local concentration, with the result that, whilst nearly all these accessories are represented by small crystals in some specimens, in others they are entirely absent. Of

these accessory minerals galena appears to be the most widely distributed, pyrites occurring next in order of abundance. Both these minerals appear to be original constituents of the rock, but the limonite and hematite are more probably secondary, as they are found infilling cavities, which, from their shapes, were apparently formed by the removal of barytes in solution by secondary causes.

SUMMARY.

The rock described in this note is composed almost wholly of quartz and barytes in the proportion of 7 of the former to 3 parts of the latter mineral. A portion of the barium in the barytes has been replaced by lime; analysis of the crystals, which have a specific gravity of 4.30, showing 4.01 per cent. of lime sulphate. With the quartz and barytes occur very small quantities of galena, pyrite, ilmenite, hematite and limonite, the last two named being of secondary origin. An assay of the rock yielded 13 grains of gold per ton.

This rock forms a large plexus of veins cutting through the pyroxenic and other gneisses between Alangayam and Andiyappanur in the Tirupatur taluk, Salem district. These veins vary in thickness from mere strings to dyke-like masses several feet across, and through them all the barytes is apparently uniformly distributed. The quartz and barytes are considered to be normal original constituents, which have separated from an injected mobile magma like many commoner pegmatites of a different composition; but no evidence is forthcoming concerning the temperature of the magma prior to consolidation. There are none of the "banded" and "comby" structures of mineral veins, and no signs of possible derivation by pseudomorphism from ordinary pegmatite.

Note on a worn femur of Hippopotamus irrawadicus, Caut. and Falc., from the Lower Pliocene of Burma, by FRITZ MOETLING, PH D., F.G.S. Palæontologist, Geological Survey of India (with Plates XIX and XX)

While mapping the country around the petroleum field of Yenangyoung I discovered on the eastern side of the Yenangyoung anticline, about 50 feet above the ferruginous conglomerate (zone of *Hippotherium antelopinum* and *Acerotherium perimense*), and about half a mile to the north from the place where the flints¹ were found, a remarkable bone sticking out from the face of a low cliff. There was no doubt that this bone was *in situ* when found by me, and that it was in an undisturbed position, there being no signs that it had been touched; in fact, it took some time to free it from its resting place.

At this place a few layers of ferruginous conglomerate are formed above the zone of *Hippotherium antelopinum*, interstratified in the soft yellow sandstone. These layers of conglomerate are sometimes only a few inches in thickness, and a few feet in length, dying out rapidly in any direction and forming therefore patches of smaller or greater extension in the sandstone.

The composition of some of these patches is a peculiar one; they are made up

¹ Rec. Geol. Surv. Ind., 1894, XXVII, pp. 101-103.

Fig. 1.



Fig. 1a

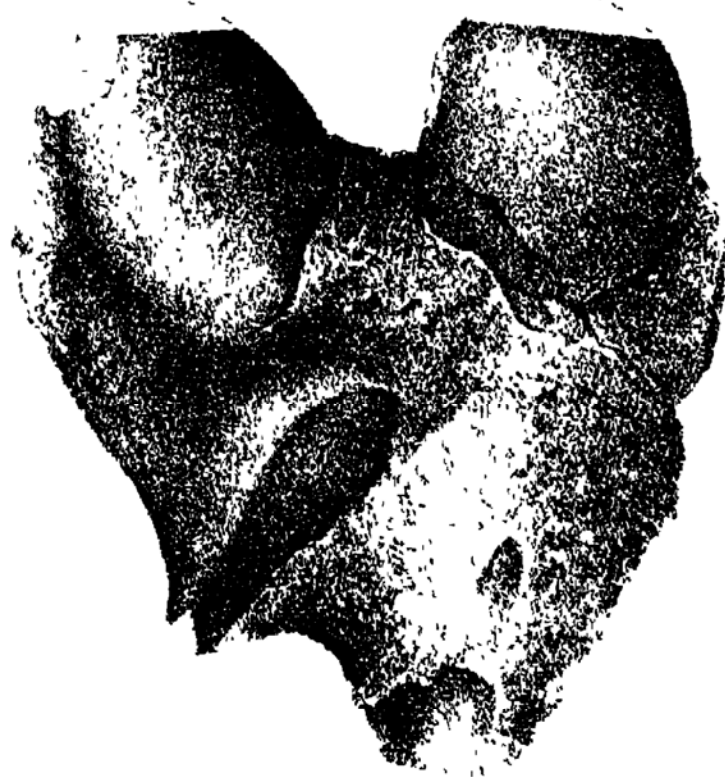


Fig. 1 Hippopotamus irrawadicus Lyd.



Fig 1



Fig 2

Fig 1 *Hippopotamus iravadicus* Lyd

Fig 2 *Equus* sp

of small pieces of drift wood fossilized into hydroxide of iron, small pebbles of white quartz, or of a ferruginous claystone, and rolled fragments of bones all mixed up together in a heap exhibiting exactly the features of a heap of shingle on the sea-shore, and it was in one of these that I discovered the femur which is the subject of this paper.

It was resting horizontally on its posterior side, lying flat, with the polished faces of the distal end directly on a layer of soft sandstone. The shingle was heaped around it but did not fully cover it. I distinctly remember that the bone had not sunk into the underlying bed, but was resting flatly on it, and I also recollect that I was particularly attracted by its remarkable position. In taking it out from the rock, a peculiar loss of substance on the ventral side of the distal condyles, where two large flat facets had been formed, at once attracted my attention, particularly as the bone was resting with these two facets on the underlying bed.

This struck me as something very peculiar, particularly as I never noticed anything similar in any of the hundreds of fragments of bones or better preserved specimens I collected around Yehangyoung. I may at once remark that I carefully looked through the Siwalik remains in the collection of the Geological Survey, but not a single specimen exhibited similar defects. It is therefore beyond doubt that whatever the verdict may be as to the origin of these curious facets, the specimen here described is at present unique.

In my paper on the tertiary system of Burma,¹ I mentioned this find for the first time, and this is what I said "A femur of probably *Rhinoceros* sp. which I found in one of these layers affords an exceedingly good illustration regarding the conditions under which they were formed. It rested with one side on a bed of sandstone and around it, and partly over it were heaped ferruginous clay—pebbles, etc., etc., now that side on which the bone rested was considerably rubbed, thus indicating the result of friction on the underlying sand, produced by the gentle rocking of the bone by the waves while lying on the beach."

It subsequently struck me that this was not quite a satisfactory explanation, but as I shall deal with this question presently, it may be left for a while. Though the peculiar feature of the femur struck me therefore at once, I refrained from making it the basis of some, perhaps, too far reaching conclusions until I noticed in the *Neues Jahrbuch*² that Professor Dames had described and figured a scapula of *Equus* the proximal end of which exhibited a similar loss of substance to the femur found by me. Professor Dames unhesitatingly attributes this loss of substance to human agency.

In the controversy which arose as to the origin of those curiously shaped flints, I discovered in the zone of *Hippotherium antelopinum* and *Acerotherium perimense*. I had quite lately an opportunity³ of giving as extensive a description of the history of the find as possible, and at the end of my paper I mentioned the femur as being probably an additional witness for the origin of the chipped flint flakes, provided the theory held by Professor Dames as to the artificial origin of the loss of substance noticed in the shoulder blade of the diluvial horse was accepted.

¹ Records, Geol. Surv. of Ind'a, 1895, Vol. XXVIII, page 77.

² Neues Jahrbuch, 1896, Bd. I, page 224.

³ On the discovery of chipped flint flakes in the Pliocene of Burma, Natural Science, 1897, Vol. X, page 2334.

Having returned from furlough, I am now in the position to give an accurate description of the femur and its peculiar features, and I leave it to the reader to judge for himself.

A careful examination of the femur has proved that it certainly did not belong to either of the genera *Mastodon*, *Elephas* or *Rhinoceros*; the greatest probability was therefore that it belonged to the genus *Hippopotamus*. As far as I can judge from the figures of Blainville and Cautley and Falconer, the general features of the femur agree very well with those of the left femur of *Hippopotamus*, but there are certainly differences, which render it almost certain that it could not have belonged to any species there described, and that with great probability it belonged to *Hippopotamus irrawadicus*, the species so clearly described by Messrs. Cautley and Falconer.

The bone measures from the middle of the distal condyles to the top of the great trochanter 600 mm. in length; the great trochanter is very large and rises above the level of the caput. The small trochanter is not very salient, rather a mere rough ridge.

The posterior or ventral side of the condyles exhibits a remarkable loss of substance; on both condyles a flat irregular facet has been formed, measuring about 50 mm. in length in axial direction. It has to be noticed that both facets do not lie in the same plane, but if the internal facet is considered as level, that on the external condyle forms an angle of about 10° with the former. On turning the femur round it will be noticed that there is also a great loss of substance on the internal side of the internal condyle;—in fact, both these worn surfaces if produced would meet at an obtuse angle on the posterior side of the internal condyle. On the anterior or dorsal side the condyles exhibit also two elongate facets; that of the internal one forming an angle of about 30° , that of the external one an angle of about 60° with the ventral facet of the internal condyle.

On turning to the proximal extremity, traces of wearing are seen both on the great trochanter and on the caput; on the great trochanter they assume such a shape as if it had been attempted to attenuate it; on both sides on the anterior as well as on the posterior side, particularly on the latter, these traces are seen.

The anterior side of the caput shows a slight trace of a facet, which is however not distinctly seen.

To sum up, the facets are exhibited on the anterior and posterior side of both extremities in such a way that they run parallel to the axis of the shaft; no facets or any other traces of wear and tear are either noticed on the shaft or on the proximal or distal face.

From the above description it is evident that this femur exhibits at both extremities, particularly on the distal one, traces of a peculiar kind of grinding. As the planes of the facets thus produced are not altogether parallel or in the same level, it is beyond doubt that those on one side cannot have been produced simultaneously, but that they must have been formed consecutively; it is quite irrelevant which was formed first; it is sufficient to know that the position of the facets proves that during their formation the bone must have been submitted to some sort of a revolving action; to form those of the distal extremity, the bone must have been turned at least five times, and whatever the medium may have been that produced the facets, it is quite evident that at one time the bone exhibited its anterior side to

the grinding process and then was turned over, exhibiting its posterior side to the same action. It may be remarked that, judging from the wearing, the process acted more vigorously on the posterior than on the anterior side.

The question now arises, how are these facets to be accounted for; were they the result of the operations of art or of those of nature? Should they be considered as intentionally wrought, are they only the result of a mere accidental process of nature resulting in loss of substance?

If we were able to answer the first question in the affirmative, then there ought to be no longer any doubt that in these facets we have the handiwork of some rational being which lived during the lower pliocene.

It may at once be said that the purpose for which these facets were made, supposing for the moment they were artificial, has no bearing on the question of their origin. For all we know, they may be the result of an idle hour after a good meal. Professor Koken at Tübingen showed me a stag's horn from the diluvial travertine of Taubach near Weimar which had been marked all over in an apparently useless manner. No doubt can exist it was human agency which produced these marks, but it is difficult to see to what purpose, unless we assume that the diluvial man who produced these marks perhaps tried to cut off some of the tines by means of his rude stone celt, and finding that it did not suit his purpose, idly hacked away at the useless bone.

It must not be forgotten that the so-called savage tribes have plenty of spare time, and I personally can state that I often observed in Kachin villages full grown men playing with a piece of wood or a stone to no purpose whatsoever. By grinding such an object on a hard surface a few hours could be pleasantly spent. There is also no doubt that children use their play-things in all sorts of manners, and a good deal of amusement results from sharpening a piece of wood or metal or bone on a stone. Although we may dismiss the notion that the heavy femur here described has been a child's plaything, we may take it as granted that the seemingly meaningless procedure resulting in the production of the facets bears no value on the decision of the question, whether they were made intentionally or were simply the result of an accidental process.

It will therefore be well to discuss first the possibilities by which in a natural way loss of substance in the above described state could be produced. The first theory which would present itself would be to attribute the loss of substance to a chemical process; to the dissolving action of some acid for instance. The question to be considered would therefore be, is it possible that by a chemical process such sharp facets on the extremities could be produced without damaging the rest of the bone. I should think that such a theory affords some serious difficulties; we have to imagine that the bone was imbedded in some substance impermeable to acids; only that small part which was to be worn off sticking out from the protecting substance. After this part had been removed, the bone was turned over, every part of it was again imbedded in the protecting substance except the one to be worn away, and so this process was repeated at least five times to produce the facets of the distal end. To imagine that while these frequent changes took place no other part of the bone should have been affected, seems highly improbable. It will certainly be admitted that if due to chemical action, the facets would probably not exhibit that fine smooth surface, but a more irregular corroded appearance.

I cannot imagine any chemical process which simply by itself without any outside assistance would produce such evenly polished surfaces at special parts of a bone. Were a bone submitted to any chemical action, I should think that its traces ought to be visible all over the surface and not restricted to certain parts. We may therefore dismiss the theory of chemical action.

The facets must therefore be the result of a mechanical action, and it remains to be seen what natural causes might have the effect above described.

The most plausible explanation is of course the action of ice as glaciers produce scratched boulders exhibiting sometimes even faces, the result of a considerable loss of substance. It is therefore by no means impossible that a strong bone such as a femur might be treated in a similar way, although I do not know of any instances which have been noticed. The possibility however must be admitted.

Is there now any trace of glacial action to be noticed in the pliocene formation of Burma? This question may be safely answered in the negative. In fact, if anything, it tends to prove that the pliocene of Burma was deposited under tropical conditions. It may be argued that some of the higher hills existing while the Irrawadi series was deposited were covered with glaciers, and that the femur may have been transported from there to the place where it was eventually found. But even granted that the glaciers did exist, such an assumption would require that the individual of *Hippopotamus irrawadicus* to which the femur belonged moved in a hilly country in a neighbourhood of glaciers, an assumption which is so contrary to all we know of the habits of *Hippopotamus* that we may safely dismiss it. But even if such a theory would be admitted, the femur should have suffered much more by transport; it could not possibly have retained its fine state of preservation, after it had been exposed firstly to glacial action and then to a journey in streams and rivers before it came to the place where it eventually found its resting place.

The next theory would be to explain the forming of the facets by the mechanical action of running water.

The action of the running water can certainly result in a considerable loss of substance, as need hardly to be mentioned. If we examine however, all water worn objects, we notice that the action of the water tends to produce a more or less rolled shape, and generally an even polished surface. Whatever the original shape of the object may have been, and whatever the substance may consist of, the action of running water always produces the same rolled shape.

It cannot well be imagined that a large bone, like the femur described, would have been mixed up with pebbles, all of a harder substance than itself, and still have retained its perfect shape while all the pebbles were rounded off. Of course, one could suppose that the femur was well jammed in between some larger pebbles or in the rocky bed of a stream; it is under such an assumption quite imaginable that the grinding action of the sand moved over it could eventually have produced the facets. But if, on the other hand, they were really produced in such a way, it is very difficult to explain why the bone should not have suffered later on when it was moved from its resting place. The perfect undamaged shape of the femur proves in my opinion that it never was associated with larger pebbles, nor that it could have undergone a longer transport in a river. If we are right in judging from the habits of the present *Hippopotamus* those of *Hippopotamus irrawadicus*, we may perhaps conclude, that the femur was originally deposited on the muddy or sandy beach of a river, perhaps partly imbedded in the soft material, only the

condyles sticking out. The question may then be raised whether the constant run of the water containing a lot of fine silt suspended, such as we notice in all tropical streams during the rainy season, has a sufficient amount of mechanical energy, to grind down of facets as above described. I cannot trace any actual observations for such a view, but I think some unquestionable proofs would be required before it could be accepted. So far, therefore, the loss of substance and the production of the facets cannot be explained by the mechanical action of running water.

The way in which the femur was deposited when I discovered it suggested at first an idea which I afterwards discovered to be an obvious impossibility. I originally believed that the specimen was lying amongst a heap of material such as is gathered frequently on a slightly inclined beach. I imagined that the action of the waves rolling ashore set the femur into a rocking motion which was sufficient to grind down the condyles producing the facets. I overlooked however a very serious objection: first, the tendency of the rocking action of the waves would be a rolling and not a grinding one, as may be noticed at any sea beach; secondly, the way in which the bone was found proves that it was resting on a sandy ground which at that time must have been soft and loose. Facets as those described could however certainly not be produced when the bone was moved by the waves while its bed was soft and yielding. Only the friction against a hard unyielding material could have produced facets, and the above view can therefore no longer hold good.

If the view of the mechanical action of ice or water cannot be sustained, the only natural action remaining which would result in loss of substance would be the action of sand blown by the wind, deflation, in fact. The faceted boulders found at numerous places, the shape of which is generally attributed to the above cause, are well known. The femur resting on a sand-bank in the river, partly imbedded in the sand, might very well have been exposed to such an influence. If the facets existed on one side only, say, for instance, the posterior one, I would unhesitatingly accept this view. But they exist on the anterior side as well, and in such a way that they could not have well been produced simultaneously. Accepting the theory of the blown sand for a moment, we have then to suppose that the facets were first produced on one side, then the bone was completely turned round so as to exhibit the opposite side, which must have been shifted once. It was then again so well imbedded that nothing but a small portion was exposed.

If this theory be accepted, of course the question is settled at once; I want however to point out a serious objection. I cannot well imagine how the movements required were carried out without exposing more than insignificant portions of the surface. In fact the facets on the anterior side are quite incompatible with this view; if they were the result of the action of blown sand, much more of the condyles should have been removed. I find a very serious difficulty in the smallness and the distribution of the facets, as I should think that, had the bone undergone this process, it would have suffered more.

In conclusion, I may mention that the view of these facets being produced by the gnawing of some wild animals is absolutely untenable. No animal could produce even surfaces, such as those described, with its teeth; there would be irregular ragged furrows, but no smooth facets if the femur had been treated by one of the large carnivorous animals.

I think that it is clear from the above arguments that to whatever known natural causes we may look as likely to produce facets as described, we meet always with some serious objections.

If, on the other hand, we suppose that the facets were intentionally made by some being, whether man, ape or *Pithecanthropus*, by holding the bone in his hands pressing it against a hard surface and grinding it down, the manufacture of the facets is easily explained.

We arrive therefore at the result that the whole state of preservation of the femur turns rather in favour of the facets being intentionally produced than accidentally. I wish however at once to say that not for a moment do I contend that the facets *must* be man's handiwork, and that there is no other cause capable of producing them. All I contend is, that very serious objections are connected with the assumption of the production of the facets by natural or accidental causes but if any one can give me any other plausible explanation, free from objections, I am quite willing to forego the conclusion that the facets are the result of the operation of an artificial agency.

Should a satisfactory explanation come forward, I think that specimens exhibiting similar loss of substance should be carefully re-examined, as to the process which caused such a loss. Professor Dames describes and figures a scapula of a horse, stated to come from the diluvial deposits of Northern Germany, exhibiting a similar, and apparently quite meaningless, loss of substance at the proximal extremity. Professor Dames unhesitatingly attributes it to human agency, but in this instance there are in fact more serious objections to such a theory than to the bone from Burma. It is quite true man has lived in diluvial times, while similar proofs are not so absolutely certain and unchallenged with regard to the pliocene period, and a bone exhibiting such features as the one described by Professor Dames and coming from diluvial beds, might only be regarded as a further instance of the existence of man during that period.

But on the other hand the history of the find is much less open to doubts in the case of the bone from Burma than in the case of the diluvial bone. The author did not find the bone himself; it was brought to him: questions may therefore be raised—did it really come from diluvial beds, and if so, was the loss of substance not produced by the tools of the workmen while unearthing it? Professor Dames holds that neither has been the case, but all the same these objections may be raised, and it will be difficult to disprove them.

In the case of the femur here described, no such objections can be raised: there were no working men which could have hurt the bone, and it was *in situ* when found by me in such a place that all ideas of subsequent influences can safely be dismissed. In fact, if one thing is certain, it is that the loss of substance was produced previously to the interment of the bone.

Not only may the above two objections be raised with regard to the diluvial bone; it may also be argued that, being found *in situ*, the glacial origin of which is no longer doubted, the loss of substance may be attributed to glacial action—a view which certainly does not enter into the question at all with regard to the femur from Burma. It is true that scratched boulders have hitherto not been found in the diluvial gravels in which the scapula is said to be found, but this is no proof against the view that the loss of substance may be the result of glacial action.

In fact if, weighing all the evidence in favour and against the artificial origin of the loss of substance in the case of the diluvial scapula, the evidence against it is rather stronger than for it—but nobody seems to have questioned the view held by Professor Dames with regard to this scapula,—may it therefore not be argued that what is accepted in this instance, also holds good for a bone exhibiting similar loss of substance, but coming from pliocene strata?

Explanation of plates.

PLATE XIX.—Fig. 1. *Hippopotamus irrawadicus*, Caut. and Falc. Left femur posterior (ventral) side, $\frac{1}{3}$ nat. size.

Fig. 1a. Ditto ditto ditto.
Distal extremity, $\frac{1}{3}$ nat. size.

PLATE XX.—Fig. 1. *Hippopotamus irrawadicus*, Caut. and Falc. Left femur, anterior (dorsal) side, $\frac{1}{3}$ nat. size.

Fig. 2. *Equus*, sp. (copy from Neues Jahrbuch, 1896, Bk. I, p. 224) reduced to $\frac{3}{4}$ size.

On the Supposed coal at Jaintia, Baxa Duars: By H. H. HAYDEN, B.A., B.E., Officiating Deputy Superintendent, Geological Survey of India.

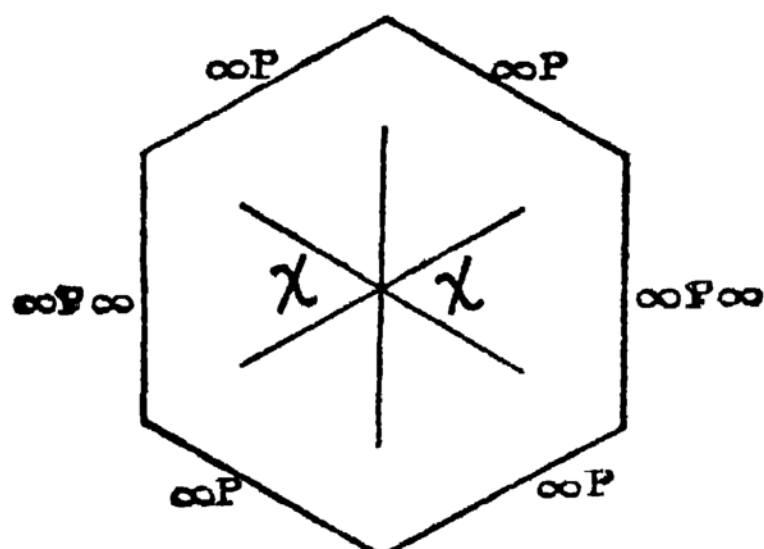
While at Kuch Bihar I was asked by Mr. D. R. Lyall to visit, if possible, the supposed coalmines near Jaintia, on the borders of Bhutan. I therefore took the opportunity, when at Baxa, of making an excursion to the spot. It is highly inaccessible and can only be reached on elephants, either from a point a few miles south of Santrabari, or from Santrabari itself. From Santrabari there is a jungle-path to Jaintia, the distance being about 8 miles. The supposed coal, which is really lignite, is found in the valleys to the north and north-east of Jaintia: the locality visited by me being about 2 miles to the E. N. E. of the village of Jaintia. Here the lignite occurs in bluish-grey and yellowish sandstones of tertiary age, which dip mostly at high angles to the S. W., but the dip is variable both in direction and amount, though always steep.

In some cases large areas—200 or 300 ft. long by 50 to 100 ft. wide—have been exposed on the plane of bedding, and the true character of the deposit is made evident. It consists of a sandstone (probably estuarine) containing isolated logs of lignite. The wood had evidently floated down the rivers and, becoming water-logged, had sunk in the estuaries, where it was embedded in the sand.

This lignite, according to an analysis made by Dr. Saise, is of very good quality, having only a small percentage of ash: but the isolated manner in which it occurs renders it of little value, and for the purpose for which I was informed it was intended, *viz.*, as the fuel supply for a railway, it would be useless. The sandstone which flanks the hills for many miles in this neighbourhood, appears to contain everywhere a certain amount of the lignite, but too scattered and in too small quantities to be of any economic value, particularly in the face of such difficulties as are presented by the inaccessibility of the locality.

Percussion Figures on Micas, by T. L. WALKER, M.A., PH.D., Assistant Superintendent, Geological Survey of India.

A short time ago, I called attention¹ to some points in regard to the percussion figures formed on plates of mica by applying the point of a large needle to a cleavage fragment and striking a sharp blow with a small hammer. The figure resulting is illustrated below. All micas agree in having six-rayed percussion figures whose rays meet at angles varying from 51° to 64° . It was generally supposed that the rays are parallel to the edges formed by the basal plane ($\circ P$) with the prism (∞P) and clinopinacoid $\infty P\infty$.



After measuring the percussssion figures on some twenty representative micas I found that this is not the case. The measurements then made were published¹ and shewed that the angles of the percussion figure opposite the clinopinacoidal edge, designated χ for convenience, varies from $52^{\circ} 53'$ to $63^{\circ} 28'$. As the micas are regarded as monoclinic, the four angles of the percussion figure, remote from the clinopinacoidal edge and adjacent to the ray which is parallel to the above-mentioned edge, are equal to one another and are different to the other two angles. It was also observed that the size of the angle χ is more or less characteristic for the species examined.

Muscovite	.	.	.	.	.	.	.	$52^{\circ} 53'$ to $55^{\circ} 57'$
Lithia Micas	.	.	.	.	.	.	.	$59^{\circ} 12'$ to $60^{\circ} 16'$
Biotite	.	.	.	.	.	.	.	about 60°
Phlogopite	.	.	.	.	.	.	.	$60^{\circ} 52'$ to $63^{\circ} 28'$

Desiring to further investigate the subject I made an examination of all the suitable micas contained in the Indian Museum. I give below the measurements of the angle χ for those micas not previously reported upon. The results in general confirm the conclusions previously arrived at, viz., the rays of the percussion figures are not parallel to the prismatic and clinopinacoid edges, but meet at

¹ American Journal of Science, Vol. II, 1896, p. 5. Observations on Percussion Figures on cleavage plates of mica.

angles varying from 51° to 64° which are more or less characteristic for the different mica species.

		°	'
Muscovite.—Hazaribagh, Bengal	.	51	49
„ Alstead, N. H., U. S. A.	.	52	3
„ Hazaribagh, Bengal	.	52	42
„ Miask, Urals	.	52	50
„ Gaya, Bengal	.	52	52
„ Narsinghpur	.	53	17
„ Vienna Exhibition (locality ?)	.	53	25
„ Nellore District, Madras	.	53	30
„ Goshen, Mass., U. S. A.	.	54	30
„ Pennsbury, Pa., U. S. A.	.	54	30
„ Nawadi, Bengal	.	54	35
Euphyllite.—S. Rewah, Central India	.	54	45
Muscovite.—Alstead, N. H., U. S. A.	.	54	47
„ Garhwal, N. W. P.	.	54	53
„ Hazaribagh, Bengal	.	54	55
„ Sirmur State, Punjab	.	55	0
„ Sutlej River, N.-W. Himalayas	.	55	16
„ Darjeeling, Bengal	.	55	27
„ Tonk, Rajputana	.	55	57
„ MacDonald Range, S. Australia	.	56	25
Lepidolite (?).—Paris, Me., U. S. A.	.	54	58
Rubellan.—Eifel, Prussia	.	59	28
Lepidomelane.—Wermland, Sweden	.	about 60	0
Biotite.—Alstead, N. H., U. S. A.	.	ditto	
„ Greenland	.	ditto	
„ Lake Baikal, Siberia	.	60	15
„ Hazaribagh, Bengal	.	60	18
Phlogopite.—S. Mirzapur, N.-W. P.	.	59	20
„ Burma (in crystalline limestone)	.	60	23
„ Travancore State	.	63	14

Notes from the Geological Survey of India.

Elæolite at Sivamalai.—An interesting discovery of elæolite-bearing rock has been made at Sivamalai in the Coimbatore district where the Sivamalai hills near Kangayam are composed of a fine grained elæolite-bearing rock, darkened by the presence of magnetite, graphite and ferro-magnesian silicates, amongst which biotite and hornblende prevail. This is cut through by veins of coarse grained rock in which the crystals of elæolite reach a diameter of 4 inches. This elæolite-bearing rock is associated with a pink pegmatite, practically devoid of quartz and containing crystals of corundum, which occurs as veins in and near the boundary of the elæolite-bearing rock. Mr. Holland has suggested that we may here look to the elæolite as the source of the alumina, of which it contains over 33 per cent., and especially points to the fact that the Sivamalai corundum has the crystal habit of Lagorios pyrogenic corundum (Zeits. f. Kryst, XXIV, 285). The field evidence is certainly consistent with the theory that the pegmatite, penetrating and absorbing the elæolite-bearing rock, acquired an excess of alumina which subsequently crystallised out as corundum.

Earthquake of 12th June.—A large number of reports have come in during the last quarter, and as one result it has been found that the area over which the shock was felt must be extended to include the whole of the Irawadi valley and delta. To the east of the Pegu Yoma, the only place from which it is reported is Pyinmana. An important report has been received from the Superintendent of telegraphs, Assam, describing how, when communications from Shillong were being reopened, it was found that, so long as the earth was used as a return, the operator was subject to electric shocks, some of considerable severity, which always accompanied one of the earthquake shocks which were constantly occurring. This, as well as the frequent interruptions of communication which accompanied the shocks, ceased as soon as a second wire was used as a return instead of the earth.

At the Magnetic Observatory at Bombay perturbations of the self-recording magnetic instruments were noticed, which it is difficult to ascribe entirely to mechanical causes, but the time at which they occurred renders it impossible for them to have been directly connected with the electric disturbances at Shillong, and if magnetic or electric at all, they must have been such as a secondary result of the mechanical effect of the earthquake wave in the immediate vicinity of Colaba.

31st October 1897.

R. D. OLDHAM.

Selection from the Assays and Examinations made in the Laboratory of the Geological Survey of India between November 1894 and November 1897.

Date.	Substance.	For whom.	Result.
13-XI-94.	One specimen of impure limonite, found in and about Mahableshwar, in the Satara District.	The Under Secretary to the Government of India, Revenue and Agricultural Department.	Quantity received: 1½ oz. Contains 46.46 per cent. of iron (Fe).
19-XI-94	One specimen of quartz, with copper pyrites, from the North Arcot District.	Edgar Thurston, Superintendent, Government Central Museum, Madras.	Quantity received: 4½ oz. Contains a trace of gold.
26-XI-94	One specimen of galena, from a hill 1 mile north-west of village Dhanpur, Kumaon.	Colonel E. E. Grigg, Commissioner of Kumaon.	Quantity received: 2lbs. 6 oz. Yielded on assay, 66.36 per cent. of lead; and 1 oz. 12 dwts. 6 grs. of silver to the ton of lead.
4-I-94	One specimen of iron pyrites, with quartz and slate, from Gohna.	Colonel D. G. Pitcher, Department of Land Records, Gwalior State.	Quantity received: 1 lb. Contains a trace of gold.
30-XII-94	One specimen of white earth, from Afghanistan.	C. W. Walsh, Martin & Co., Calcutta.	Lithomarge, allied to Fuller's earth, with some pieces containing graphite.

Date.	Substance.	For whom.	Result.
3-XII-94	Specimens collected in Eastern Persia.	Surgeon-Major G. W. Brazier Creagh.	The majority are from the mountains Taftan, Basman, Hamant and Fanach.
	<i>Taftan</i> is an active volcano from which sulphur and sal ammoniac were obtained. <i>Basman</i> is volcanic, but not now active. Sulphur was also obtained here. <i>Hamant</i> and <i>Fanach</i> doubtful. (B.—C.)		
	No. I.	Salt from Tank-i-Nimak, North of Amadi, 6 stages N. of Bandar Abbas. The nala is white with salt. Tombstones from an old cemetery in the Kosh Valley under the lofty Taftan, an active volcano. Inscriptions supposed to be very old. (B.—C.)	
	No. II.	A. Specimens from Fanach hill. Elevation 4,860 feet. Amongst the rocks are specimens of a partially decomposed troctolite (originally an olivine plagioclase rock). The other specimens are red clay with partings of calcite, lumps of limestone, pale green epidote and silicified magnesite: probably not far removed from serpentine. B. Specimens from the rocky bed of Fanach pass. Mostly limestones, partly crystalline and in some cases evidently derived from infilled cracks. Specimens of red clay rock are generally silicified, but cracks are also filled in with calcite. These and the green rocks resemble volcanic ash beds. One specimen is a mixture of quartz and light green epidote.	
	No. III.	Fragments of limestone and quartz from hills between camp Abgar and Itchan. Elevation 1,900 feet.	
	No. IV.	Limestone, partly silicified and dolomitized, from hills between Gordahan and Isfaka.	
	No. V.	Specimens from Hamant hill. Elevation 7,623 feet. Said to be a dormant volcano. Shales baked and silicified, dolomites and magnesites with veins of calcite, veins of quartz and epidote. Specimens of talcose schist. Specimens of serpentine said to occur in huge masses. Geh hills. Elevation 1,400 feet. Specimen of brown marl, with veins of quartz and dirty calcite containing carbonate of iron. Silicified red shale with veins of quartz. Specimen of dark green, compact and well jointed rock containing carbonate of lime, possibly compact ash bed. Specimens of fibrous calcite. Sand from Bampur Dasht near Geskok Camp. Elevation 1,800 feet. Dirty calcareous quartz sand with semi-rounded grains.	
	No. VI.	"A. Specimens from Koh-i-Cheltan or Taftan or Koh-i-Naushadir (sal ammoniac). Volcanic peak 12,800 feet (approx.)." Pumice and fragmental rocks (tufts and ash) of an andesitic volcanic outburst. Considerable quantities of infiltrated calcite in most specimens. Native sulphur with small quantities of soluble sulphates and chlorides.	
	No. VII.	Mak or Lak—a yellowish marl from Cheltan Range, which, with leaves of the Kangak shrub, makes a black dye called Lak-i-Siah, and with leaves of the pomegranate makes purplish yellow dye. As the specimen sent contains large quantities of sulphate of iron, doubtless it is this substance which combines with the tannic acids of the leaves to produce a black tannate of iron. The aqueous extract of the same substance with pure tannic acid gives a deep blue-black ink. The iron compounds will also, of course, give different colours with other leaves in which the tannic acids are present in a different form.	
	No. IX.	Hill in sandy desert near camp Geskok. Lumps of carbonate of lime (like kunkur) and conglomerate cemented with carbonate of lime.	

Date.	Substance.	For whom.	Result.
	No. X. A, Specimens of rocks from Basman peak, a dormant volcano. Elevation 11,200 feet. Andesitic ejectamenta. Andesites with rhombic pyroxenes, as in the case of Koh-i-Cheltan, and with flakes of brown mica. Some specimens fragmental and pumiceous, but of the same family. Lumps of carbonate of lime apparently from infillings of cracks. B. Sulphur from same locality. C. Limestone fragments from Koh-i-Alman range, part of Basman. Elevation 4,000 feet.		
	No. XI. A. Specimens from hills near Basman village. Specimens of hornblende-biotite granite. Lumps of quartz rock and hardened lithomarge. Specimens of decomposed pumice. Masses of limestone, some pieces well crystallised. B. Dark calcareous earth with scales of biotite, same locality. C. and D. Volcanic agglomerate composed of various minerals, fragments of pumice, etc., all impregnated with carbonate of lime and salt. E. Slab of hornblende-andesite.		
15-11-95	Three specimens from the summit of Babargarh, Waziristan.	H. A. Casson, C.S., Political Officer, Bannu Column, Bannu.	Nos. 1 and 2, basic volcanic agglomerate. No. 3, iron pyrites.
4-III-95	One specimen of clay from the Lameta group, Warora, Central Provinces.	Geo. R. Reynolds, Manager, Warora Colliery.	Contains 83.63 per cent. of Silica (SiO ₂).
20-IV-96	Two specimens from the Kaira District, Gujerat.	J. Walter Leather, F.C.S., etc., Agricultural Chemist to the Government of India.	No. 1, earthy hematite. No. 2, limonite nodules (possibly pebbles) in a matrix of carbonate of lime.
1-III-95	Specimens from the Salem District.	C. S. Middlemiss, B.A., Deputy Superintendent, Geological Survey of India.	No. 17, dunite, partly altered into serpentine. S.G. 2.961. Silica (SiO ₂). 36.64% Magnesia (MgO) 46.12% No. 18, dunite: S. G. 3.176. Silica (SiO ₂) 39.1% Magnesia (MgO) 48.26% No. 19, magnetite schist. S. G. 3.538. Contains 36.66% of iron (Fe). No. 20, magnetite schist. S. G. 3.365. Contains 35.00% of iron (Fe). No. 21, magnetite schist. S. G. 3.415. Contains 32.40% of iron (Fe).
6-VI-95	One specimen of coal, containing iron pyrites, from Yen-angyoung, Upper Burma.	F. Noetting, Ph. D., Palaeontologist, Geological Survey of India.	Moisture 8.54 Volatile matter 37.40 Fixed carbon 42.80 Ash 11.26 100.00 Does not cake. Ash—dark greyish red.

Date.	Substance.	For whom.	Result.																
6-VI-95	One specimen of limonite from about two miles south-east of Jate, Porahat District, Lohardagga Division.	W. Anderson, Geological Survey of India.	Contains 36.68 per cent. of iron (Fe).																
8-VII-95	Two specimens of iron ore from Rewah.	P. N. Datta, B. Sc., Deputy Superintendent, Geological Survey of India.	A. Manganiferous hematite, limonitic. Foot of Kymore scarp, north-west of Baghwar, near Bourgaona, Rewah. Contains 50.43 per cent. of iron (Fe). B. Limonite. Half mile north-east of Sulkma village, Ramnagar Tahsil, Rewah. Contains 20.47 per cent. of iron (Fe).																
12-XII-95	Galena from a hill about 14 miles east of Madeya, Mandalay.	H. H. Hayden, Assistant Superintendent, Geological Survey of India.	Quantity received: 2 lbs. 7 oz. Yielded on assay, 53.42 per cent. of lead; and 4 oz. 14 dwts. 17 grs. of silver to the ton of lead.																
12-XII-95	Quartz from old gold workings at Chin-nathaganu, Udu, Kollegal Taluq, Coimbatore District.	C. S. Middlemiss, Superintendent, Geological Survey of India.	Quantity received: 8 lbs. Yielded on assay, a trace of gold.																
10-I-96	Three specimens of quartz, and one of schist, from Porahat, Chota Nagpore.	C. L. Griesbach, Director, Geological Survey of India.	1. "Quartz reef (2)" Quantity recd. 10 lbs. 2. "Takraburn No. 4 cutting" " 7 " 3. "Ragolburn hill" " 9 " 4. Schist " 1 1/2 " Yielded on assay, no gold.																
6-III-96	One specimen of crushed quartz, from 23 miles S.S.E. of Balarampur, Bengal Nagpur Railway, for gold.	C. L. Griesbach, Director Geological Survey of India.	Quantity received: 19 lbs. Yielded on assay, 1 dwt. 9 grs. of gold per ton.																
10-IV-96	Seven specimens of crushed quartz, from 23 miles S.S.E. of Balarampur, Bengal Nagpur Railway, for gold.	W. Anderson, Specialist, Geological Survey of India.	<table><tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>Quantity recd.</td><td>8 lb.</td><td>6 lb.</td><td>4 lb.</td><td>8 lb.</td><td>4 lb.</td><td>4 lb.</td><td>4 lb.</td></tr></table> Contain no gold.		1	2	3	4	5	6	7	Quantity recd.	8 lb.	6 lb.	4 lb.	8 lb.	4 lb.	4 lb.	4 lb.
	1	2	3	4	5	6	7												
Quantity recd.	8 lb.	6 lb.	4 lb.	8 lb.	4 lb.	4 lb.	4 lb.												
30-IV-96	Two specimens from Port Blair for determination.	Major R. C. Temple, Superintendent of Port Blair.	Specimen from Flat rock Invisible bank, about 60 miles South East of Port Blair. Marine sedimentary organic limestone, with granules of plagioclase felspar and hornblende, derived from some older volcanic rocks; organisms foraminifera, radiolaria, etc. The rock belongs to Oldham's Archipelago series of late Tertiary age. Specimen found off anchorage at North-West end of Narcondam. Magnetite sand, with grains of quartz, ilmenite and felspar, evidently derived from the basaltic rocks of Narcondam.																

Date.	Substance.	For whom.	Result.																		
13-V-96	Two specimens of coal, from Rewah State.	R. D. Oldham, A.R.S.M., F.G.S., Offg. Director, Geological Survey of India.	<table><tr><td>GARWANI.</td><td>SINDHOA, NEAR KARSWA.</td></tr><tr><td>Quantity received : 1 lb. 11 oz.</td><td>Quantity received : 3 lbs. 3 oz.</td></tr><tr><td>Moisture . 2'08</td><td>4'60</td></tr><tr><td>Volatile matter . 8'72</td><td>26'00</td></tr><tr><td>Fixed carbon . 44'76</td><td>41'12</td></tr><tr><td>Ash . 44'44</td><td>28'28</td></tr><tr><td>100'00</td><td>100'00</td></tr><tr><td>Ash—reddish grey.</td><td>Ash—grey.</td></tr><tr><td>Does not cake.</td><td>Does not cake.</td></tr></table>	GARWANI.	SINDHOA, NEAR KARSWA.	Quantity received : 1 lb. 11 oz.	Quantity received : 3 lbs. 3 oz.	Moisture . 2'08	4'60	Volatile matter . 8'72	26'00	Fixed carbon . 44'76	41'12	Ash . 44'44	28'28	100'00	100'00	Ash—reddish grey.	Ash—grey.	Does not cake.	Does not cake.
GARWANI.	SINDHOA, NEAR KARSWA.																				
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100'00	100'00																				
Ash—reddish grey.	Ash—grey.																				
Does not cake.	Does not cake.																				
29-V-96	One specimen of auriferous quartz, from the old workings in Kollegal Taluq (Tippoo's Mines), Madras.	C. S. Middlemiss, B.S., Superintendent, Geological Survey of India.	Quantity received : 2 lbs. 6½ oz. Yielded on assay, 2 oz. 5 dwts. 17 grs. of gold per ton.																		
9-VI-96	One specimen of coal, from centre of broadest bands, Mithwa coal-field, about 1½ miles from Thathannah N. N.-W. Upper Burma.	H. H. Hayden, B.A., B.E., Assistant Superintendent, Geological Survey of India	Quantity received 8 lbs. <table><tr><td>Moisture</td><td>6'16</td></tr><tr><td>Volatile matter</td><td>33'48</td></tr><tr><td>Fixed carbon</td><td>24'64</td></tr><tr><td>Ash</td><td>35'72</td></tr><tr><td></td><td>100'00</td></tr></table> Ash—light grey. Does not cake.	Moisture	6'16	Volatile matter	33'48	Fixed carbon	24'64	Ash	35'72		100'00								
Moisture	6'16																				
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Fixed carbon	24'64																				
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	100'00																				
10-VI-96	Three specimens of iron ore, from Rewah State.	P. N. Datta, B.Sc., F.G.S., Deputy Superintendent, Geological Survey of India.	1. Limonite, S. W. of Lukaora. Quantity received : ½ lb. Contains 35'76 per cent. Iron (Fe). 2. Limonite, ½ mile N. by E. of Paujerio H. S. Quantity received : 14 oz. Contains 48'75 per cent. Iron (Fe). 3. Hematite, near Puri, S.-W. of Harma on the Son. Quantity received : 11 oz. Contains 44'32 per cent. Iron (Fe).																		
30-VI-96	A specimen of limonite concretion, from Nyaungsigyin, Pagan district, Upper Burma.	H. H. Hayden, B.A., B.E., Assistant Superintendent, Geological Survey of India.	Quantity received : 4½ oz. Contains 44'12 per cent. Iron (Fe).																		
14-VIII-96	One specimen of quartz, from Balarampur, Manbhum district.	W. Anderson, Specialist, Geological Survey of India.	Quantity received : 78 lbs. Yielded on assay, a trace of gold.																		

Date.	Substance.	For whom.	Result.																
2-X-96	Specimens of amalgam tailings, and blanketings, the result of two trial crushings, of 15 and 9 tons quartz.	W. Anderson, Specialist, Geological Survey of India.	1. Mohalbana, Manbhum district. Amalgam, from bottles marked 1, 4 and 7, from 9 tons crushed quartz. Yielded on assay, 1'24 grs. of gold, equal to '138 grs. per ton. 2. Chandra Dhobni, Manbhum district. Amalgam, from bottles marked 2, 3, 5 and 6, from 15 tons crushed quartz. Yielded on assay, '095 grs. of gold, equal to '0063 grs. per ton. 3. Tailings, from 9 tons crushed quartz. Yielded on assay, a trace of gold. 4. Tailings, from 15 tons crushed quartz. Yielded on assay, a trace of gold. 5. Blanketings, from 15 tons crushed quartz. Yielded on assay, a trace of gold.																
3-VIII-96	One specimen of quartz, from the Singbhoom district.	A. E. Wild, Conservator of Forests, Bengal.	Contains a trace of gold.																
14 I-97	One specimen of Lignite, containing plant remains and specks of resin, found at the bottom of a well, 201 feet from surface, Pallana, about 12 miles from Bikaner, Rajputana.	Lieut.-Col. H. A. Vincent, Political Agent, Bikaner.	Quantity received : 7 lbs. <table><tr><td>Moisture</td><td>12'50</td></tr><tr><td>Volatile matter</td><td>41'40</td></tr><tr><td>Fixed carbon</td><td>37'50</td></tr><tr><td>Ash</td><td>8'60</td></tr><tr><td></td><td> </td></tr><tr><td></td><td>100'00</td></tr></table> Does not cake. Ash—light grey.	Moisture	12'50	Volatile matter	41'40	Fixed carbon	37'50	Ash	8'60				100'00				
Moisture	12'50																		
Volatile matter	41'40																		
Fixed carbon	37'50																		
Ash	8'60																		
	100'00																		
5-I-97	Three specimens of minerals, for determination.	Geo. Watt, Reporter on Economic Products to the Govt. of India.	No. 1.—From Kabul. Travertine. No. 2.—From Sakesar and Kalabagh, Punjab. Massive gypsum. No. 3.—From Kabul. Borvenite (Pseudo Jade).																
17-XII-96	One specimen of Psilomelane. from Gosalpur, Jabalpur district, for phosphorus.	C. W. McMinn, Jabalpur.	Contains '589 per cent. phosphoric anhydride (P ₂ O).																
8-III-97	A white mineral, found underneath the coal strata, Chitteenand, Salt Range, supposed to be Bauxite.	Museum, Geological Survey of India, Calcutta.	S. G. 1'707. <table><tr><td>SO₃</td><td>23'63</td></tr><tr><td>H₂O</td><td>46'44</td></tr><tr><td>Az₂O₃</td><td>30'08</td></tr><tr><td>CaO</td><td>trace.</td></tr><tr><td>Fe₂O₃</td><td>"</td></tr><tr><td>ZnO.</td><td>"</td></tr><tr><td></td><td> </td></tr><tr><td></td><td>100'15</td></tr></table> —Aluminite. Amethyst.	SO ₃	23'63	H ₂ O	46'44	Az ₂ O ₃	30'08	CaO	trace.	Fe ₂ O ₃	"	ZnO.	"				100'15
SO ₃	23'63																		
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CaO	trace.																		
Fe ₂ O ₃	"																		
ZnO.	"																		
	100'15																		
8-III-97	Three specimens from Bahahar, supposed to be Sapphire.	R. G. Thomson, C. S., Deputy Commissioner, Simla District.																	

Date.	Substance.	For whom.	Result.					
10-III-97	Six specimens of coal from the Warora Colliery.	C. O. Leefe, Assistant Secretary to Chief Commissioner, Public Works Department, Central Provinces, Nagpur.		"No. 4 pit, Far north district, 3 seam."	"No. 4 pit, rise Bar district 3 seam."	"No. 5 pit, 18 rise, 3 seam."	"No. 5 pit, S. A. R., 3 seam."	"No. 5 pit, Main dip, 3 seam."
			Quantity received.	10lbs.	10lbs.	10lbs.	10lbs.	10lbs.
			Moisture	8'40	9'78	26'52	7'40	6'38
			Volatile matter.	29'00	29'62	27'10	20'48	19'64
			Fixed carbon.	42'74	43'72	40'08	36'44	31'62
			Ash	19'86	16'88	26'30	35'08	42'36
				100'00	100'00	100'00	100'00	100'00
			Do not cake.					
			Ash—pale reddish grey.		Ash—reddish grey.	Ash—reddish grey.	Ash—light grey.	Ash—light grey.
11-III-97	One specimen of Galena, from Arki, Baghal State, Simla Hills.	R. G. Thomson, C.S., Deputy Commissioner, Simla District.	Quantity received: 2 1/2 lbs. Yielded on assay, 75'17 per cent. lead (Pb); and 21 oz. 1 dwt. 9 grs. silver to the ton of lead.					
10-IV-97	Four specimens of coal from Assam.	F. H. Smith, Geological Survey of India.		I. 5 1/2 oz.	II. 7 oz.	III. 5 1/2 oz.	IV. 4 1/2 oz.	
			Quantity received.					
			Moisture .	5'36	3'88	3'14	7'10	
			Volatile matter.	49'96	57'52	29'00	37'48	
			Fixed carbon.	25'32	25'40	15'24	40'38	
			Ash .	19'36	13'20	52'62	15'04	
				100'00	100'00	100'00	100'00	
			Sinters slightly. Ash—light buff.		Sinters slightly. Ash—light buff.	Does not cake. Ash—light buff.	Does not cake. Ash—dark reddish brown.	

Date.	Substance.	For whom.	Result.		
12-V-97	Two specimens of coal, from Assam.	F. H. Smith, A.R.C.S., Deputy Superintendent, Geological Survey of India.	Quantity received.	A. 10 $\frac{3}{4}$ oz.	B. 4 oz.
			Moisture	10'74	9'40
			Volatile matter	31'12	34'42
			Fixed carbon	25'90	26'32
			Ash	32'24	29'86
				<u>100'00</u>	<u>100'00</u>
				Does not cake.	
				Ash—white.	Ash—pale white.
18-V-97	One specimen of lignite with specks of resin, from Pallana, 12 miles from Bickaner, Rajputana.	Tom. D. LaTouche, B.A., Superintendent, Geological Survey of India.	Quantity received: 45lbs.		
			Moisture		8'20
			Volatile matter		42'72
			Fixed carbon		39'48
			Ash		9'60
					<u>100'00</u>
			Sinters slightly, but does not cake.		
			Ash—light brown.		
			Calorific power in heat units (C), 7,293.		
			Evaporative power, 13'58.		
10-VI-97	A heavy metallic looking specimen from the Koderma Government Forest, Hazari. bagh District, supposed to be iron.	A. Gow-Smith, Hastings House, Alipore.	Columbite; S. G. 6'19.		
9-VIII-97	Pebbles of schist containing quartz, Wa States, Burma, for gold assay.	The Chief Secretary to the Government of Burma, per J.G. Scott, Superintendent of the Northern Shan States, Burma.	Quantity received : 14lbs.		
			Contains 10'5 grains of gold to the ton.		

Date.	Substance.	For whom.	Result.																																																																		
18-IX-97	A specimen of the granite from Uramalia quarry $\frac{1}{2}$ mile S. W. of Karasamir, S. Arcot District. For bulk analysis.	T. H. Holland, Officiating Superintendent, Geological Survey of India.	<table><tr><td>Si₁ O₂</td><td>.</td><td>.</td><td>.</td><td>.</td><td>58'30</td></tr><tr><td>Al₂ O₃</td><td>.</td><td>.</td><td>.</td><td>.</td><td>20'76</td></tr><tr><td>Fe₂ O₃</td><td>.</td><td>.</td><td>.</td><td>.</td><td>2'59</td></tr><tr><td>Fe O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>3'84</td></tr><tr><td>Ca O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>8'38</td></tr><tr><td>Mg O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>2'62</td></tr><tr><td>Na₂ O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>4'21</td></tr><tr><td>K₂ O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'71</td></tr><tr><td>Ignition</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'20</td></tr><tr><td colspan="5">TOTAL</td><td>101'61</td></tr></table>	Si ₁ O ₂	.	.	.	.	58'30	Al ₂ O ₃	.	.	.	.	20'76	Fe ₂ O ₃	.	.	.	.	2'59	Fe O	.	.	.	.	3'84	Ca O	.	.	.	.	8'38	Mg O	.	.	.	.	2'62	Na ₂ O	.	.	.	.	4'21	K ₂ O	.	.	.	.	'71	Ignition	.	.	.	.	'20	TOTAL					101'61						
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Ignition	.	.	.	.	'20																																																																
TOTAL					101'61																																																																
18-IX-97	A hand specimen of hypersthene, hornblende granite from Perumbakam, Madras. For bulk analysis.	Ditto . .	<table><tr><td>Si₁ O₂</td><td>.</td><td>.</td><td>.</td><td>.</td><td>61'40</td></tr><tr><td>Al₂ O₃</td><td>.</td><td>.</td><td>.</td><td>.</td><td>19'38</td></tr><tr><td>Fe₂ O₃</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'58</td></tr><tr><td>Fe O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>5'27</td></tr><tr><td>Ca O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>6'56</td></tr><tr><td>Mg O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>3'24</td></tr><tr><td>Na₂ O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>2'78</td></tr><tr><td>K₂ O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'44</td></tr><tr><td>Ignition</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'15</td></tr><tr><td colspan="5">TOTAL</td><td>99'80</td></tr></table>	Si ₁ O ₂	.	.	.	.	61'40	Al ₂ O ₃	.	.	.	.	19'38	Fe ₂ O ₃	.	.	.	.	'58	Fe O	.	.	.	.	5'27	Ca O	.	.	.	.	6'56	Mg O	.	.	.	.	3'24	Na ₂ O	.	.	.	.	2'78	K ₂ O	.	.	.	.	'44	Ignition	.	.	.	.	'15	TOTAL					99'80						
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TOTAL					99'80																																																																
21-IX-97	Alkaline salt from Yenangyat, Upper Burma, where it occurs as an incrustation and is more or less impure.	G. E. Grimes, Assistant Superintendent, Geological Survey of India.	The portion soluble in hot water was analysed separately—the insoluble portion is given below under the heading of "Insolubles." Reaction distinctly alkaline. <table><tr><td>Na₂ O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>34'89</td></tr><tr><td>K₂ O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'24</td></tr><tr><td>Ca O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>1'25</td></tr><tr><td>Mg O</td><td>.</td><td>.</td><td>.</td><td>.</td><td>1'80</td></tr><tr><td>S O₃</td><td>.</td><td>.</td><td>.</td><td>.</td><td>48'09</td></tr><tr><td>Cl</td><td>.</td><td>.</td><td>.</td><td>.</td><td>'32</td></tr><tr><td>Ignition</td><td>.</td><td>.</td><td>.</td><td>.</td><td>4'65</td></tr><tr><td>Insolubles</td><td>.</td><td>.</td><td>.</td><td>.</td><td>10'00</td></tr><tr><td colspan="5"></td><td>101'24</td></tr><tr><td colspan="5">Less oxygen equivalent</td><td>'08</td></tr><tr><td colspan="5">TOTAL</td><td>101'16</td></tr></table> This analysis shows that the substance contains about 78 per cent. Na₂ S O₄, with smaller quantities of Ca S O₄ and Mg S O₄.	Na ₂ O	.	.	.	.	34'89	K ₂ O	.	.	.	.	'24	Ca O	.	.	.	.	1'25	Mg O	.	.	.	.	1'80	S O ₃	.	.	.	.	48'09	Cl	.	.	.	.	'32	Ignition	.	.	.	.	4'65	Insolubles	.	.	.	.	10'00						101'24	Less oxygen equivalent					'08	TOTAL					101'16
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Less oxygen equivalent					'08																																																																
TOTAL					101'16																																																																

DONATIONS TO THE MUSEUM.

FROM 1ST AUGUST TO 31ST OCTOBER 1897.

Specimens of Muscovite, with tourmaline and ferruginous inclusions, from the Koderma Government Forest, Hazaribagh District.

PRESENTED BY A. GOW-SMITH,
KODERMA, HAZARIBAGH DISTRICT.

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